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Research Report 1537

Backward Transfer and Skill Acquisition in the AH-1 Flight and Weapons Simulator

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and

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U.S. Army Research Institute Aviation
Research and Development Activity

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Research accomplished under contract for the Department of the Army

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Backward Transfer and Skill Acquisition in the AH-1 Flight and Weapons Simulator

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Two experiments were conducted, one to investigate the backward transfer of flight skills to the AH-1 Flight and Weapons Simulator (AH1FWS) and another to investigate the acquisition of flight skills in the AH1FWS on selected maneuvers. In the backward transfer research, 16 AH-1 instructor pilots (IPs) from the AH-1 Aircrew Qualification Course were administered checkrides in the AH1FWS and the AH-1F aircraft. Comparison of the performance data from the two checkrides indicates that, while proficient on the maneuvers in the AH-1F, all IPs performed poorly in the AH1FWS. The IPs attributed their difficulties in the AH1FWS to deficiencies in the visual system and the handling and response characteristics of the flight controls.

In the skill acquisition research, four groups of 10 operational aviators received training in the AH1FWS. Each group received training on a different set of five maneuvers. The training comprised 10 practice trials for each maneuver. Subjects (Continued)

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received no feedback on trials 1-3; IPs provided instruction on trials 4-10. Mean performance ratings did not reach a satisfactory level of proficiency within the 10 practice trials for 17 of the 20 maneuvers investigated. Furthermore, the backward transfer data obtained during the skill acquisition research were consistent with similar data collected in a previous study.

The authors con "1FWS deficiencies adversely affect pilot performance on select ..ers. However, the extent to which these simulator deficiencies ma ct subsequent pilot performance in the aircraft has not been determine. The research results provide evidence that the AH-1F aircraft and the AH1FWS are not interchangeable training devices and that forward transfer of training research is required. In addition, the results support the utility of the backward transfer paradigm as a potentially useful means of estimating forward transfer of training and as a relatively inexpensive testbed for the development of experimental procedures.

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FOREWORD

This research, performed within the Training Research Laboratory by the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, was accomplished under the sponsorship of the U.S. Army Aviation Center (USAANVC) as an Annex to the Memorandum of Agreement (MOA) between ARIARDA and the Directorate of Training and Doctrine, dated 15 March 1984.

Over the past two decades, the Army has made a significant investment in the development and acquisition of motion-based visual flight simulators for its rotary wing aircraft. As training resources have decreased and the competition for those resources has increased, training in high-fidelity flight simulators has been viewed as a cost-effective alternative to aircraft flight training.

The primary function of these high-fidelity flight simulators is to support aircrew training in operational aviation units. However, little empirical data to document the training effectiveness of these simulators or to support the development of effective and efficient flight simulation instructional programs exist. A research approach designed to generate the empirical data needed to support Army officials' decisions about the employment of Army flight simulators was developed. The research plan addresses the problems of training effectiveness on a task-by-task basis for the initial skill acquisition and subsequent skill sustainment of flying skills.

This document reports the results of the first research conducted in the AH1FWS and includes the results from (a) a backward transfer investigation of emergency touchdown maneuvers (ETMs), and (b) an investigation of simulator skill acquisition for the ETMs, standard contact maneuvers, nap-of-the-earth maneuvers, and hovering tasks. The backward transfer research evaluated the ability of highly proficient aviators to perform selected maneuvers in the prototype model of the AH1FWS. The simulator skill acquisition research determined the rate at which operational unit aviators learned to perform selected maneuvers in the production model AH1FWS.

These results were briefed to the Deputy Chief of Staff for Operations and Plans - Training Directorate (DAMO-TR), USAAVNC Command Group, and Directorate of Training and Doctrine. Other briefings to operational personnel were accomplished over a period of approximately 6 months, commencing in July 1986. The outcome of these briefings produced a renewed emphasis on the conduct of flight simulator training and initiated additional interest for a further examination of flight simulator effectiveness, and in particular, gunnery training. This information will

be useful in developing effective flight simulation training strategies.

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Technical Director

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Charles A. Gainer, Chief, U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA), Fort Rucker, Alabama, served as the Contracting Officer's Technical Representative for this research, and Dr. Thomas M. Longridge, ARIARDA, served as the Technical Leader. Dr. Dennis H. Jones, Anacapa Sciences, Inc., assisted in the development of the research designs and participated in the first data collection effort.

CW3 Kenneth Donahue and CW3 Dwain Hartwick, Flight Standardization Division, Directorate of Evaluation and Standardization, U.S. Army Aviation Center, Fort Rucker, Alabama, served as standardization instructor pilots for all checkrides conducted at Fort Rucker. They also provided subject matter expertise during the development of evaluation gradeslips and procedures.

AH-1 instructor pilots from Company A, 7th Aviation Training Battalion, Aviation Training Brigade, Fort Rucker, Alabama, served as subjects during the portion of the project conducted at Fort Rucker. Major Richard L. McGlothlin, Commander, Company A, served as the point of contact at the 7th Aviation Training Battalion. He scheduled participation of the instructor pilots and arranged for the operational flying support required during the project.

BACKWARD TRANSFER AND SKILL ACQUISITION IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

EXECUTIVE SUMMARY

This report describes the methods and results of two experiments that evaluated aviator training performance in the AH-1 Flight and Weapons Simulator (AH1FWS). The research, conducted by the U.S. Army Research Institute Aviation Research and Development Activity (ARIARDA), constitutes the first phase of a research program designed to determine the effectiveness of the AH1FWS for training operational aviators.

Requirement:

The Army has made a significant investment in the development and acquisition of motion-based, visual flight simulators for training aviators in rotary wing aircraft. As the costs of aircraft resources have increased, high-fidelity flight simulators have been viewed as effective alternatives for conducting flight training. High-fidelity flight simulator systems are being acquired for distribution to the operational aviation units with the AH-1, AH-64A, CH-47D, and UH-60 aircraft. The primary function of these flight simulators is aircrew training.

Procedure:

The overall objective of this research was to evaluate the effectiveness of the AH1FWS for training critical flight maneuvers and tasks in Army aviation units. Two experiments were conducted, a backward transfer experiment, and a skill acquisition experiment. The specific objective of each experiment is as follows:

Backward transfer experiment. The primary objective of the backward transfer experiment was to measure the proficiency of AH-1 aviators during their initial exposure to the AH1FWS. Eight emergency touchdown maneuvers (ETMs) were investigated, including five currently prohibited in Army aircraft. The backward transfer experiment provided information about these areas:

- the aviators' initial levels of proficiency on the maneuvers in the AH-1F aircraft,
- the aviators' levels of proficiency on their first trial of the maneuvers in the AH1FWS, and

- the aviators' opinions about how AH1FWS characteristics either enhanced or degraded their performances.

Skilled acquisition experiment. The primary objective of the skill acquisition experiment was to measure the rate at which operational unit aviators acquired their highest level of proficiency on selected maneuvers in the AH1FWS. Fifteen different maneuvers were investigated, including standard contact, nap-of-the-earth, tactical, and the eight ETM maneuvers from the backward transfer experiment. Five of the maneuvers were investigated in both the pilot and copilot/gunner positions. The skill acquisition experiment provided information about these areas:

- the aviators' initial levels of proficiency on the maneuvers in the AH1FWS,

- the rates at which the aviators acquired flight skills on selected maneuvers in the AH1FWS, and

- the aviators' proficiency levels after 10 practice trials of each maneuver in the AH1FWS.

Findings:

Flight performance in the AH1FWS was poor during the backward transfer experiment. Performance was rated as "Very Poor" on 82 percent of the trials completed in the AH1FWS, in contrast to 27 percent of the trials completed in the AH-1F. Furthermore, 44 percent of the AH1FWS trials terminated in a crash. The AH-1 instructor pilots participating as subjects in the backward transfer experiment attributed their performance difficulties to deficiencies in (a) the simulator's visual system, and (b) the AH1FWS control handling qualities.

Similarly, performance was poor on all maneuvers performed during the skill acquisition experiment. However, AH-1 aviators demonstrated significant improvement in performance across 10 training trials on all but four of the maneuvers. The aviators required several training trials to reach a satisfactory level of proficiency on all maneuvers investigated. The average number of trials required to attain satisfactory proficiency ranged from 9 for Manual Throttle Operation in the pilot station to an estimated 28 for Hovering Tasks in the copilot/gunnery station.

Utilization of Findings:

The results indicate that significant differences exist between the AH1FWS and the AH-1F, and that the two training devices should not be considered as interchangeable. Transfer-of-training research should be conducted to identify, by task, the training effectiveness of the AH1FWS in the operational

training environment. The results of the transfer-of-training research may provide a data base to support the development of more effective and efficient flight simulator programs of instruction.

BACKWARD TRANSFER AND SKILL ACQUISITION IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

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BACKWARD TRANSFER AND SKILL ACQUISITION IN THE AH-1 FLIGHT AND WEAPONS SIMULATOR

INTRODUCTION

Background

As aviation training resources have diminished, competition for those remaining resources has escalated. Increased attention is being focused on high fidelity flight simulators as a cost-effective alternative to aircraft flight training. Research efforts to determine the effectiveness of the current generation of flight simulators have been stymied by the intensive training schedules maintained in the devices. The limited amount of research conducted, while generally yielding positive results, is inconclusive. Without an in-depth assessment of the training benefits derived from their use, no formal or centralized training strategy has been developed for the Army's flight simulators.

Nevertheless, the Army currently is acquiring 39 high fidelity flight simulators to support aviator training. The majority, consisting of 7 AH-1 Flight and Weapons Simulators (AH1FWS), 15 UH-60 Flight Simulators (UH60FS), 5 CH-47 Flight Simulators (CH47FS), and 6 AH-64 Combat Mission Simulators (AH64CMS), will be delivered to operational aviation units and will be available to support training no later than April 1990. The remainder, consisting of two AH1FWSs, two UH60FSs, one CH47FS, and one AH64CMS, have been installed and will be used for institutional training at the U. S. Army Aviation Center (USAAVNC).

Recently, Army agencies have documented the need for empirical data to determine the optimal use and benefits of flight simulators. For example, after auditing the Army's Synthetic Flight Training System (SFTS) program in 1981, the Army Audit Agency (AAA) concluded that there were insufficient data to justify either the total number of flight simulators scheduled for purchase or the plan for dispersing simulators to aviation units (U. S. Army Audit Agency, 1982). Of particular concern to the AAA was (a) the lack of sufficient justification for the plan to deploy the AH1FWS, CH47FS, and UH60FS, and (b) the failure to quantify the reductions in flying hour programs that can be realized through the use of flight simulators. The AAA recommended that the Army initiate a program of research to address these issues.

As a result of the AAA findings, the Assistant Secretary of the Army for Research, Development, and Acquisition requested that the Commander, U. S. Army Materiel Command

(AMC), form a Flight Simulator Steering Group to plan future Army flight simulator research. The group's membership was drawn from AMC, the Training and Doctrine Command (TRADOC), and the Army Research Institute Aviation Research and Development Activity (ARIARDA). In response to the Secretary's directives, ARIARDA conducted a detailed literature review (Ryan-Jones, 1984) and developed a detailed research plan that addresses both the design of future flight simulators and the utilization of simulators presently in the Army's inventory (Cross & Gainer, 1983). However, the support and resources required to conduct the research were not provided.

In 1984, the AAA conducted a follow-up audit of the Army's SFTS, with results similar to those of the first audit. The AAA criticized the Army for failing to respond adequately to AAA's previous finding that empirical data are needed to justify the planned acquisition and dispersal of flight simulators (U. S. Army Audit Agency, 1985). The AAA questioned the Army's decision to procure a large number of motion-based, visual flight simulators for use in operational units without (a) identifying operational aviators' training needs, and (b) demonstrating that training in flight simulators provides the most cost-effective method of satisfying those needs. The AAA did not criticize the role of flight simulators to support institutional training.

The Commander, USAAVNC, responded to the 1985 AAA report by directing the Directorate of Training and Doctrine (DOTD) to initiate two research programs. First, DOTD was directed to obtain information that would support tentative decisions concerning simulator fielding and utilization through implementation of an interim research program. Second, DOTD was directed to plan and initiate research designed to provide empirical data that will enable the Army to develop long-range plans for optimal simulator fielding and utilization. These taskings are discussed in the following two subsections.

Interim Research

In 1986, DOTD analysts responded to the first tasking by employing modified Delphi techniques to collect subject matter expert (SME) estimates of the types and amount of flight simulator training required by operational aviators. Results from the Delphi research are reported by Shurtz et al. (1986) and Dees and Byars (1986). Shurtz et al. queried separate panels of AH-1, UH-60, and CH-47 SMEs about annual training requirements (number of flight hours) for aviators training in each of the three simulator types. In addition, Shurtz et al. surveyed a larger number of operational aviators to validate the data obtained from the SME panel.

Dees and Byars (1986) collected opinions from 289 operational aviators regarding the estimated amount of flight simulator training required to reach proficiency on combat and basic flight maneuvers. Dees and Byars combined these data with those reported by Shurtz et al. (1986) to provide estimates of simulator and aircraft training required to maintain operational aviators at optimal levels of combat proficiency.

ARIARDA Research Program

DOTD requested that ARIARDA address the second USAAVNC tasking. ARIARDA responded with the research plans developed earlier by Cross and Gainer (1983; 1987). The plans identified three specific objectives for simulator research:

- quantify the relationship between training fidelity and training effectiveness,
- define the relationship between flight simulator life-cycle cost and training fidelity, and
- define the type, cost, and training effectiveness of training methods and media that represent alternatives to simulator training.

The ARIARDA research plan recognized the need to address these objectives for the simulators currently owned by the Army and for those that the Army will design and build in the future. Therefore, Cross and Gainer proposed that two complementary paths of research be conducted concurrently. The two complementary research paths are a Long-Term Path and a Short-Term Path.

Long-term path. The Long-Term Path of research addresses issues relevant to the design of future flight simulators. It consists of basic and exploratory research concentrating on:

- fidelity requirements for visual systems,
- fidelity requirements for motion systems,
- fidelity requirements for simulator displays and controls,
- fidelity requirements for simulator handling qualities, and
- requirements for instructional support features.

Short-term path. The Short-Term Path is a program of research designed to evaluate and improve the use of the flight simulators that the Army already has acquired or has contracted to purchase. These include the AH1FWS, UH60FS, CH47FS, and AH64CMS. The design of these flight simulators is already fixed or will be fixed before the Long-Term Path of research can be completed. Thus, the objectives of the Short-Term Path are twofold: (a) determine the best way to employ the flight simulators that have been or are soon to be fielded, and (b) identify design modifications that will improve the training effectiveness of fielded simulators without incurring a considerable cost for product improvement. Figure 1 presents a task-flow diagram of the Short-Term Path.

The Short-Term Path of research focuses on the use of flight simulators for training aviators who have completed institutional training and have been assigned to operational aviation units. The plan states that the simulators should be evaluated on a task-by-task basis for each of the operational aviation unit training requirements.

Operational aviation unit training requirements differ substantially from institutional training requirements. The USAAVNC conducts two types of institutional flight training courses: the Initial Entry Rotary Wing Course and Aircrew Qualification Courses (AQCs) for each type of aircraft. In these courses, student aviators learn the basic flight skills and some rudimentary tactical skills. The institutional courses develop individual skills rather than crew and team skills. Operational training requirements include the development of crew and team skills. In addition, operational training programs must:

- provide for skill enhancement and skill sustainment as well as skill acquisition;
- address a wider range of individual, crew, and team tasks; and
- be appropriate for operational aviators who are qualified and current in the aircraft, but vary greatly in their flight experience.

Moreover, training requirements vary from one operational unit to another, depending on the unit's location and combat mission.

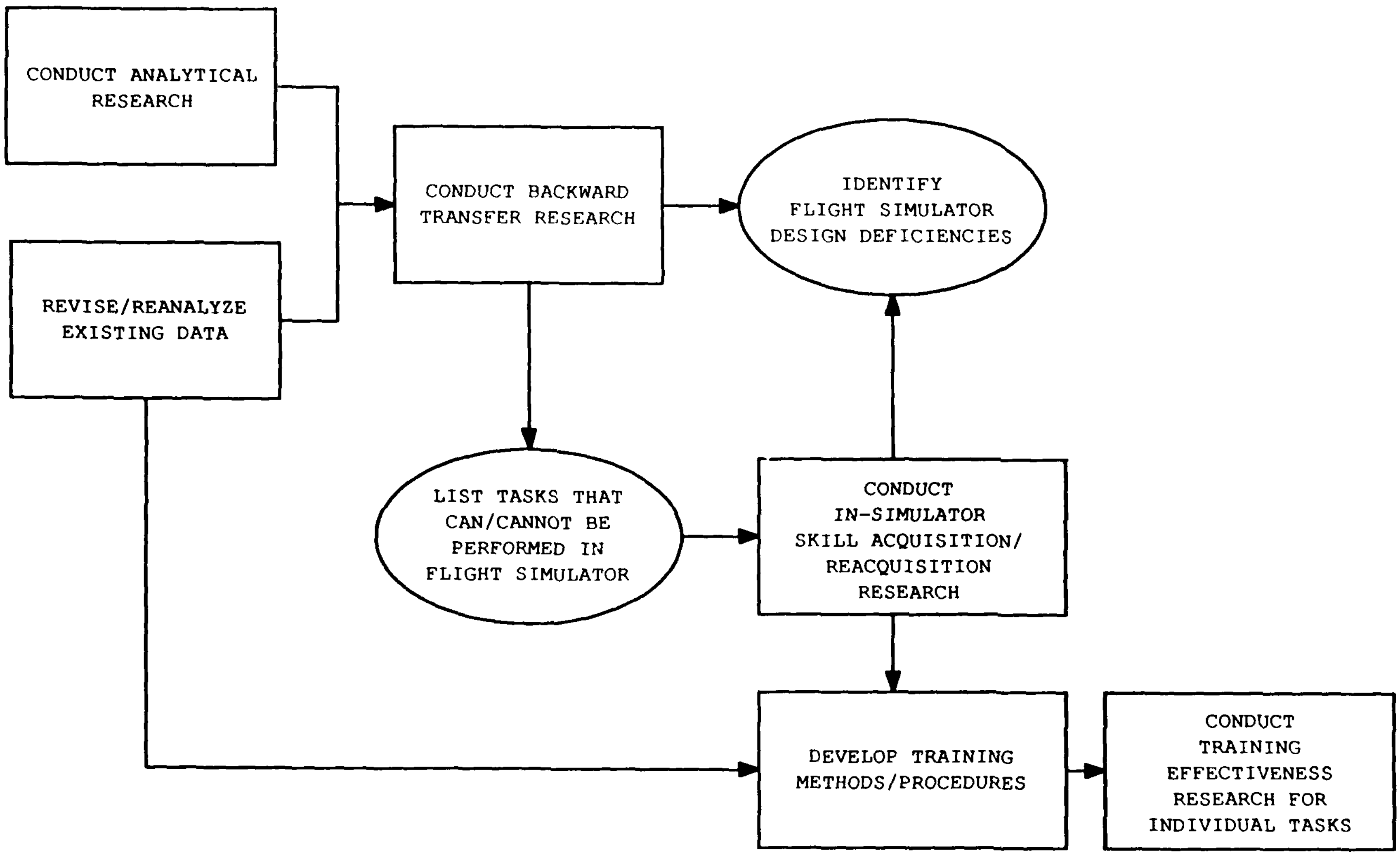

Figure 1. Task-flow diagram for the Short-Term Path of research.

Aviators entering operational aviation units immediately after institutional training possess individual skills that enable them to pilot aircraft. However, they lack the proficiency necessary to employ the aircraft in combat. Therefore, the Short-Term Path of research proposes to investigate the effectiveness of flight simulators for the enhancement of basic flight skills, the acquisition of new individual, crew, and team skills (particularly gunnery and tactical skills), and the sustainment of proficiency over time.

Review of Relevant Literature

Only a few researchers have investigated the training effectiveness of rotary wing flight simulators: Holman (1979) evaluated the training effectiveness of the CH47FS; Bridgers, Bickley, and Maxwell (1980) evaluated the training effectiveness of the AH1FWS; and Luckey, Bickley, Maxwell, and Cirone (1982) conducted operational tests of the UH60FS. The primary purpose of these investigations was to evaluate the respective flight simulator's training effectiveness when incorporated into an established program of instruction (POI) for the aircraft's AQC. The research reported by Holman and by Bridgers et al. also investigated the effectiveness of the CH47FS and AH1FWS for training aviators assigned to aviation units. Both the Holman and Bridgers et al. research is discussed in further detail below.

CH47FS Research

Holman (1979) reported results from two investigations of the CH-47C flight simulator's training effectiveness: one for institutional training and one for aviation unit training. In the research of institutional training, an experimental group of 24 student aviators completed a program of instruction in the CH-47C flight simulator, followed by the same program of instruction in the CH-47C aircraft. A control group of 35 student aviators completed the program of instruction only in the aircraft. Performance data were collected for 32 different maneuvers included in the program of instruction. Holman reported positive transfer of training for all 32 of the maneuvers investigated in the institutional environment.

Holman's (1979) second investigation consisted of an evaluation of the CH-47C flight simulator's effectiveness for maintaining flying skills over a period of 6 months. The subjects were 32 qualified and current CH-47C pilots assigned to operational units. The 16 subjects assigned to the control group received no training in the flight simulator, but flew an average of 58.0 mission support hours in the CH-47C aircraft during the 6-month test period. The 16 subjects assigned to the experimental group received 30 hours

of training in the flight simulator and also flew an average of 45.2 mission support hours in the aircraft over the 6-month test period. All subjects were administered pretest and posttest checkrides; each checkride consisted of 35 flight tasks in the aircraft. Holman reported a significant improvement from the pretest to the posttest for the simulator trained group, but no significant difference between the two groups on the posttest checkride scores. Holman attributed the improved posttest checkride scores for the experimental group to simulator training alone and concluded that the CH-47C flight simulator was effective as a training device for the maintenance of flight skills.

However, the conclusions drawn by Holman (1979) are confounded by four factors.

- First, Holman did not equate the two groups for prior flight experience or for flight proficiency. The initial checkride scores indicate that the experimental group was significantly less proficient than the control group.

- Second, structured training was provided only to the experimental group. Aviators in the experimental group received formal instructions on the tasks under investigation, but no instruction was provided to the control group.

- Third, both groups received substantial amounts of flight time in the aircraft during the test period, but the type and amount of flying was not controlled. Most of the tasks investigated (e.g., hovering flight, normal takeoff, internal and external loads) are common to mission support flights accomplished in the CH-47C aircraft. Therefore, the experimental group received substantial amounts of practice in the aircraft on many of the target tasks.

- Fourth, conclusions about the capabilities of the CH-47C flight simulator for maintaining flight proficiency are unwarranted, because Holman did not demonstrate that skills on the target tasks normally degrade over a period of 6 months. In fact, subsequent research (Ruffner & Bickley, 1985) demonstrated that contact flight skills do not degrade significantly during a total abstinence from flying UH-1 aircraft for a period of 6 months.

AH1FWS Research

Bridgers et al. (1980) evaluated the AH1FWS in both the institutional and operational aviation unit settings. The institutional evaluation investigated the effectiveness of

the AH1FWS for training 32 tasks prescribed in the AH-1 AQC program of instruction. The operational aviation unit evaluation investigated the effectiveness of the AH1FWS for maintaining skills on gunnery and contact flight tasks.

In the first experiment, student pilots assigned to an experimental group were trained in the AH1FWS to a specified level of proficiency on all of the tasks included in the AH-1 AQC program of instruction. Following training in the flight simulator, the student pilots in the experimental group were trained to the same level of proficiency in the AH-1 aircraft. Student pilots in the control group received training to proficiency only in the AH-1 aircraft. Bridgers et al. (1980) reported positive forward transfer for all of the 32 maneuvers investigated.

In the second effort, 12 aviators assigned to operational Army aviation units received a pretest checkride consisting of 3 gunnery and 16 flight tasks in the AH-1 aircraft. The aviators then practiced the tasks in the AH1FWS for an average of 6.4 training periods (period = 1.5 hours). After completing the training, they were administered a posttest checkride on the same tasks in the AH-1 aircraft. The data indicated that simulator training produced no improvement in gunnery skills, but, to some extent, sustained contact flying skills. However, the researchers did not employ a control group; all subjects experienced the same experimental conditions. Because of the small number of subjects and the lack of experimental controls, Bridgers et al. (1980) concluded that their research was unsuccessful in evaluating the effectiveness of the AH1FWS for aviation unit training.

Thus, there is a paucity of empirical data that evaluates the effectiveness of flight simulators for conducting flight training. The research reported by Holman (1979), Bridgers et al. (1980) and the Delphi research reported by Shurtz et al. (1986) and by Dees and Byars (1986) represents the entire body of literature concerning the effectiveness of Army flight simulators for training aviators assigned to operational aviation units. Confounding variables render the results inconclusive; however, they do provide a foundation for planning future research to investigate the training effectiveness of flight simulators. The lessons learned previously served as a guide for planning the Short-Term Path of research and the two experiments presented in this report.

Objectives

ARIARDA decided initially to implement the Short-Term Path of research by investigating a single flight simulator system, the AH1FWS. Factors considered in selecting the AH1FWS include (a) the number of simulators available at

operational aviation units, and (b) the variety of tasks that are potentially trainable in the flight simulator.

In their Short-Term Path of research, Cross and Gainer ([illegible]; 1987) describe two preliminary steps that must be completed prior to conducting research to collect training effectiveness data. The two preliminary steps are:

- define the degree to which flight skills transfer from the aircraft to the flight simulator, and

- determine, for each training task, the rate at which aviators acquire skills in the flight simulator.

This report presents results from two experiments designed to address these two preliminary steps. The objective of Experiment 1 is to assess the degree to which flight skills for performing eight emergency maneuvers transfer from the AH-1F to the AH1FWS. The objective of Experiment 2 is to assess the rate of skill acquisition in the AH1FWS for an expanded group of flight maneuvers. The results of Experiment 1 and Experiment 2 are presented in the next two sections of this report.

EXPERIMENT 1: BACKWARD TRANSFER OF EMERGENCY TOUCHDOWN MANEUVERS

Introduction

Training effectiveness research with high fidelity simulators is expensive to conduct. Minor simulator hardware or software deficiencies can render the research results useless, require expensive replications, or lead to faulty conclusions. Therefore, relatively inexpensive experiments should be conducted prior to the implementation of full-scale training effectiveness research. For example, backward transfer experiments may (a) validate simulator functioning, (b) identify minor configuration changes that will optimize simulator functioning, (c) determine the amount of simulator-unique learning that is required to attain criterion level performance in the flight simulator, and (d) predict results expected from forward transfer-of-training experiments.

Backward Transfer Research

Adams and McAbee (1961) first described the backward transfer-of-training method of evaluating training simulators. In backward transfer research, operators who are proficient on the relevant training tasks in the aircraft are required to perform the same tasks in the simulator. If the operator can perform the tasks in the simulator without practice, then backward transfer has occurred. The demonstration of backward transfer provides evidence that forward transfer of training from the simulator to the aircraft probably will occur, although the exact quantity is unknown.

Adams and McAbee (1961) cautioned that generalization of results obtained with skilled aviators in backward transfer experiments may be unwarranted. First, experienced, proficient aviators may possess highly generalized skills that are not possessed by novice aviators. These general skills, rather than the specific skills needed to operate the aircraft or to accomplish a mission, may allow an experienced aviator to operate the simulator. Second, a simulator may present the cues necessary to evoke a particular set of behaviors from skilled performers, but it may not present the cues essential for developing the same set of behaviors in student aviators. Therefore, a backward transfer experiment may provide information important to an analysis of simulator training effectiveness by delineating proficiency differences between skilled and less skilled pilots.

The backward transfer experimental design is simple and can be performed on any simulator system. An analysis of backward transfer is conducted on a task-by-task basis for

each potential application of the flight simulator. The subjects are required to demonstrate proficiency on the tasks of interest in the aircraft and to have no experience in the flight simulator. The backward transfer research proceeds in two steps. First, the subjects are administered a checkride in the aircraft to assess their level of proficiency on each task under investigation. Second, the subjects' ability to perform the target tasks in the flight simulator are assessed without benefit of prior practice in the flight simulator.

The primary assumption of this paradigm is that, during the first trials in the flight simulator, the aviators will attempt to apply the same set of skills that is successful for them in the aircraft. If the aviators demonstrate proficiency in the aircraft but cannot perform the target tasks successfully in the flight simulator, poor performance must be attributed to deficiencies in the flight simulator. The presence of backward transfer (i.e., subjects can perform the target tasks adequately in both the aircraft and the flight simulator) provides evidence that a high level of fidelity exists in the simulator. This also indicates that skills learned in the flight simulator probably will transfer to the aircraft. However, backward transfer data provide no means for estimating the magnitude of positive forward transfer.

Emergency Touchdown Maneuvers

An important issue associated with the Army's fielding of motion-based, visual flight simulators concerns their effectiveness for training skills on maneuvers that normally are not practiced in the aircraft. Some tasks are either too expensive (e.g., weapons related tasks) or too dangerous (emergency maneuvers) for aircrews to practice in the aircraft. One group of these maneuvers is the five emergency touchdown maneuvers (ETMs) listed below:

- Standard Autorotation,
- Low Level Autorotation,
- Low Level High Speed Autorotation,
- Antitorque Failure, and
- Simulated Dual Hydraulic Systems Failure.

In the past, aviators were required to develop and maintain proficient skills on each of these maneuvers throughout all phases of their training. However, in 1983, it was determined that the Army incurred more losses from accidents resulting from training aviators to perform ETMs than from accidents resulting from real aircraft failures. Consequently, in November 1983, a decision was made to institute a

1-year moratorium on the practice of these five maneuvers in rotary wing aircraft (Department of the Army, 1983). In 1984, a permanent prohibition against practicing the ETMs was instituted by deleting them from the lists of flight tasks in the Aircrew Training Manuals (ATMs). Further, this prohibition against practicing ETMs was incorporated into Army Regulation 95-1: General Provisions and Flight Regulations (Department of the Army, 1985).

The only exceptions to this prohibition occur within the AQCs and the Instructor Pilot Courses (IPCs). In the AQCs and IPCs, student aviators are trained to proficiency and administered evaluation flights on the ETMs. However, under the prohibition, the pilots are not permitted to practice the ETMs following graduation.

The prohibition against ETMs has created a training deficiency for Army aviators. The Directorate of Evaluation and Standardization (DES) at the USAAVNC has estimated the ETM proficiency of operational aviators by observing their performance upon assignment from aviation units to the IPCs. Farnham and Rowe (1986) reported the results of checkrides administered to 106 aviators entering the IPCs at the USAAVNC for the UH-1 (n = 67), AH-1 (n = 19), and OH-58 (n = 20) aircraft. The checkrides comprised four maneuvers that the Army permits in the aircraft and eight maneuvers that the Army does not permit in the aircraft. Instructor Pilots (IPs) and Standardization Instructor Pilots (SIPs) conducted the checkrides and evaluated student performance on a 6-point subjective rating scale. The lower three scale values (1 - 3) were verbally anchored to unsatisfactory performance and the higher three scale values (4 - 6) were verbally anchored to satisfactory performance.

Performance on the permitted maneuvers received an average rating of 4.00 on the 6-point scale, while performance on the prohibited maneuvers received an average rating of 2.97. The majority performance level on each prohibited maneuver was unsatisfactory, except for Dual Hydraulics Failure. For four of the prohibited maneuvers (Dual Hydraulics Failure, Standard Autorotation, Low Level Autorotation, and Low Level High Speed Autorotation), the majority of subjects required verbal assistance to complete the maneuvers successfully. For the other four prohibited maneuvers (Low Level High Speed Autorotation, Left and Right Antitorque Failures, and Autorotation with 180° Turn), the majority of subjects required physical assistance to complete the maneuvers successfully. The authors generalized these results and concluded that operational unit aviators do not possess sufficient skills to perform the prohibited maneuvers satisfactorily.

In addition, Farnham and Rowe (1986) compared their data with similar data obtained in 1985. These comparisons revealed no significant differences between the performance observed in 1985 and in 1986. Farnham and Rowe concluded that, although skills had degraded to unsatisfactory levels between 1983 and 1985, the skill degradation stabilized between 1985 and 1986.

There also is anecdotal information indicating that the adverse effects of the ETM prohibition extend beyond the performance of the five emergency maneuvers. Aviators report that training conducted under extreme conditions in the aircraft prepares them not only to handle emergency conditions successfully, but also to function as better pilots under normal flight conditions. The aviators argue that the ETM training familiarizes them with aircraft handling qualities and flight characteristics, and that the mastery of complex emergency situations instills confidence and a positive attitude. Therefore, although the ETM prohibition may be cost effective, it likely results in an aviator population that is less proficient in both emergency and normal flight conditions.

An alternative means of maintaining proficiency on the ETMs would be of great value. Intuitively, flight simulator training provides the most logical alternative to aircraft training for the ETMs because the aviators can practice these maneuvers without endangering themselves or their equipment. Most tasks can be trained in a flight simulator with interpolated aircraft practice, but this is not the case for ETMs. The only opportunity an aviator has to verify proficiency on an ETM is during a real inflight emergency, when the aviator has only one chance to complete the maneuver successfully. Bad habits or inappropriate techniques acquired and maintained in the flight simulator could prove disastrous during the real inflight emergency. If simulator training teaches aviators inappropriate techniques or strategies, it may prove better for aviators not to practice specific maneuvers in flight simulators. Therefore, the effectiveness of flight simulators for training and maintaining appropriate skills should be evaluated empirically before ETM training is introduced to flight simulator training programs.

ARIARDA investigated the training effectiveness of the AH1FWS by conducting a backward transfer experiment with the five ETMs. The research objective was to determine if skills appropriate for performing the ETMs in flight are also appropriate for performing the same maneuvers in the AH1FWS.

Method

Subjects

Sixteen highly experienced, male AH-1 aviators served as subjects for this experiment. At the time the research was conducted, all 16 aviators were serving as IPs in the AH-1 AQC at the USAAVNC, Fort Rucker, Alabama. The 16 subjects were chosen by the company commander from the pool of approximately 35 AQC IPs; the commander based subject selection on the IPs' availability from other duties.

Descriptive data on the age and flight experience of the subjects are shown in Table 1. As a group, the IPs were experienced aviators who had logged a median of 4,150 hours in rotary wing aircraft and 1,000 hours as AH-1 IPs. Moreover, at the time the research was conducted, the IPs reported that they performed a median of 11 ETMs per week and supervised students in the performance of 57.5 ETMs per week. Although the ranges show substantial variation among IPs in both hours logged and ETMs performed/supervised, even the least experienced IP (minimum total flight hours = 1100) must be considered a seasoned, highly skilled AH-1 aviator.

Table 1

Age and Flight Experience of 16 Subjects

	Median	Range
Age (Years)	36.5	26 - 41
Total Rotary Wing Hours	4150.0	1100 - 5800
Total AH-1 Hours	2200.0	800 - 4300
Hours as an AH-1 IP	1000.0	100 - 2100
Number of ETMs Supervised Per Week	57.5	20 - 90
Number of ETMs Performed Per Week	11.0	5 - 45

Shortly before the research was initiated, the AH1FWS was upgraded from an AH-1S configuration to an AH-1F configuration. None of the IPs who served as subjects had flown the upgraded configuration of the AH1FWS prior to their participation in the research.

Evaluators

Two DES SIPs volunteered to serve as evaluators for the research. Table 2 shows their age and flight experience. All DES SIPs are required to maintain aircraft proficiency on the ETMs; their normal duties require them to evaluate the

Table 2

Age and Flight Experience of Evaluators

	Evaluator 1	Evaluator 2
Age (Years)	37	34
Total Rotary Wing Hours	4500	4200
Total AH-1 Hours	4000	3900
Hours as AH-1 IP/SIP	3000	2100
Number of ETMs Supervised Per Week	25	25
Number of ETMs Performed Per Week	2	2

AQC IPs' flight and instructional skills on all flying tasks, including ETMs.

Equipment

Two AH-1F aircraft and an AH1FWS were employed in this research. The two AH-1F aircraft were employed to assess the in-aircraft flight skills of all subjects. The AH1FWS employed for this research is located at the USAAVNC; its characteristics are fully described elsewhere (Department of the Army, 1984a). The AH1FWS has a pilot cockpit and a copilot/gunner (CPG) cockpit, each mounted on a separate six-degree-of-freedom motion platform. An instructor/operator station is located directly behind the crew station in both the pilot and CPG cockpits. Visual scenes are displayed in the pilot's station on two channels (forward and left) and on a single visual channel (forward) in the CPG station. Visual scenes are produced by a camera model system traversing a three-dimensional terrain modelboard replicating a generic gaming area of approximately 7.3 kilometers by 19.5 kilometers at a scale of 1:1000.

Maneuvers

The eight maneuvers selected for study are listed in Table 3, along with their respective ATM task number (Department of the Army, 1984b). The Army does not permit operational aviators to practice the first five maneuvers (3000 series) listed in Table 3 in the aircraft. The remaining three maneuvers (1000 series) are emergency maneuvers that all operational aviators practice routinely in the aircraft. For simplicity in the remainder of this report, the term ETM refers to all eight of the maneuvers investigated. A complete description of each maneuver is presented in Appendix A. Descriptions and evaluation guidelines for the eight maneuvers were drawn from the AH-1

Table 3

Eight Maneuvers Selected for Investigation in the Backward Transfer Research

Maneuver	ATM Task Number
Standard Autorotation (SA)	3001
Low Level Autorotation (LLA)	3002
Simulated Dual Hydraulic Systems Failure (SHF)	3003
Simulated Right Antitorque Failure (SRAF)	3004
Low Level High Speed Autorotation (LLHSA)	3005
Shallow Approach to a Running Landing (SARL)	1030
Manual Throttle Operation (MTO)	1056
Stabilization Control Augmentation System (SCAS) Off Flight	1059

ATM (Department of the Army, 1984b) and the AH-1 Operator's Manual (Department of the Army, 1980).

Performance Measures

Subjective evaluations of pilot performance were the principal performance measures employed in this research. DES SIPs evaluated each trial attempted by each subject in both the aircraft and the AH1FWS, using a two-part gradeslip. The first part of the gradeslip, completed during the trial, is a series of scales that provide detailed information about performance during each phase of the maneuver. The second part of the gradeslip is an overall performance rating (OPR) that was completed immediately following the trial. Once completed, the gradeslip provides a record of what the aviator did during each phase of a maneuver and how well he did it. The characteristics of the gradeslips are more fully discussed in the following paragraphs.

Gradeslip background. The Pilot Performance Description Record (PPDR), developed by Smith, Flexman, and Houston (1952) and later modified by Greer, Smith, and Hatfield (1962) and by Prophet and Jolley (1969), served as a model for the gradeslips used in the present experiment. Smith et al. developed the PPDR to reduce the subjectivity present in evaluations of pilot performance and to provide a method for standardizing flight evaluations. Greer et al. demonstrated that OPRs made with PPDR descriptive scales are more reliable than OPRs made without the PPDR. Versions of the PPDR have been used effectively to evaluate aviator flight performance in a variety of investigations (see Shelnutt, Spears, & Prophet, 1981; Childs, Prophet, & Spears, 1981; Childs,

Spears, & Prophet, 1983). The reader is referred to Smith et al., Greer et al., and Prophet and Jolley for a complete description of how their respective PPDRs were developed; a brief description of the procedures used in this research follows.

Gradeslip development. A separate gradeslip was designed for each maneuver investigated in the experiment. Although the design requirements for the gradeslips were outlined, final development relied heavily on the SIPs' expert knowledge of flight evaluation and the mechanics of the maneuvers to specify the content of the gradeslips. The SIPs first identified the major segments of each maneuver (e.g., entry, approach, touchdown) and then identified flight parameters that must be considered to evaluate aviator performance within each segment. Finally, the SIPs identified the criteria they use to evaluate performance on each parameter. The gradeslips included a scale for rating each flight parameter considered relevant to the evaluation of performance on the maneuvers. These scales were anchored to established standards and tolerances for performance on each parameter and enabled the evaluator to indicate quickly how well the subject performed relative to each standard. The AH-1 ATM (Department of the Army, 1984b) and the AH-1 Operator's Manual (Department of the Army, 1980) provided guidelines for defining performance criteria.

The flight parameters defined by the SIPs can be classified into three categories: objective parameters, subjective parameters, and categorical parameters. Objective parameters can be evaluated by reading values directly from a flight instrument, by reading a display on the AH1FWS' operator console, or by referencing objects located outside the cockpit, such as runway markings. Subjective parameters cannot be assessed by reading values directly from an instrument or display, but rather, require a judgment from the evaluator (e.g., touchdown cushion). Categorical parameters are objective in nature but are used when performance can fall into only two or three categories (e.g., rotor RPM being satisfactory, too high, or too low).

A bipolar 13-point rating scale, anchored to the appropriate standard and tolerance, was constructed for most parameters. An example of one of the 13-point scales (entry airspeed) is presented in Figure 2. For this parameter, the standard for entering the maneuver was 100 knots indicated airspeed (KIAS), with a tolerance of ± 10 KIAS. The evaluators were instructed to mark the point on the scale corresponding to the subject's airspeed at entry and to mark the appropriate extreme box if the subject exceeded the specified tolerance for the parameter. In the case of Entry Airspeed, the evaluator marked the SLOW box if the subject entered the

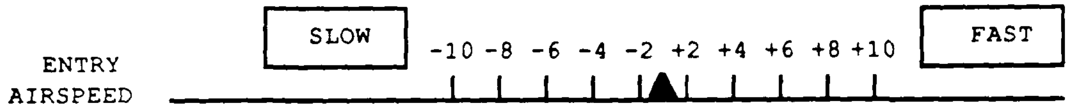

Figure 2. Bipolar 13-point parameters rating scale.

maneuver at less than 90 KIAS and the FAST box if he entered the maneuver at more than 110 KIAS. Therefore, the evaluator was able to mark quickly the direction and magnitude of deviations from the defined standards.

Several parameters did not require bipolar rating scales either because deviation from the standard was possible in only one direction or because the full range of performance was represented adequately by two or three categories. For example, a landing could be scored as either acceptable or too hard, but it could not be scored as too soft. In all cases, the descriptive rating scales enabled the evaluators to describe quickly an aviator's performance on any given trial by marking the magnitude and direction of a deviation from the defined standard.

The SIPs recorded their OPRs on a bipolar 13-point rating scale ranging in value from -6 to +6 (see Figure 3). Three verbal descriptors anchored the scale, including "Unsat" at -6, "Average AQC IP" at zero, and "Excellent" at +6. The evaluators were instructed to refer to individual parameter ratings and to base their ratings on their expectations of performance for the average AQC IP. All unsatisfactory performance was rated as "Unsat" or -6. All other scale values represented varying degrees of proficiency within a range of acceptable performance.

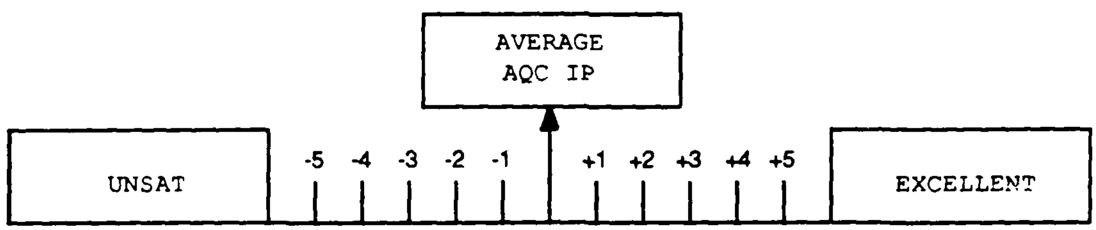

Figure 3. Bipolar 13-point OPR scale for Experiment 1.

Evaluator Training

Previous researchers (e.g., Greer et al., 1962) have emphasized the importance of employing evaluators who are well trained in (a) the descriptive rating scales and standards, (b) the maneuvers to be evaluated, (c) the sources of rater bias, and (d) the requirement to mark ratings on the

scales quickly, accurately, and safely. In this experiment, most of the problems inherent in training evaluators were alleviated because the two SIPs who performed all of the performance evaluations also participated in the development of the gradeslips. Both SIPs became intimately familiar with the rating scales, standards, and evaluation procedures prior to the beginning of data collection.

In addition, each evaluator received approximately 10 hours of training in the AH1FWS and 3 hours of training in the AH-1F on the use of the gradeslips. During this training, emphasis was placed on the SIPs' dual role as evaluators and data recorders. Their previous IP training had emphasized the evaluation of aviator performance instead of the objective description of performance at the level of detail required by this project. Therefore, the SIPs were instructed that their goals during data collection were to record accurate (a) detailed descriptions of aviator performance and (b) overall ratings of aviator performance.

Data Collection Procedures

Data were collected during a 4-day period when the subjects were free from their normal flight instructor duties. The data collection procedures are discussed below in the order in which they were performed.

Assign subjects to evaluators. Because of time constraints, it was not possible for a single evaluator to conduct all of the aircraft checkrides. Hence, the subjects were assigned randomly to one of the two evaluators, with the limitation that the two evaluators administer an equal number of aircraft checkrides. As discussed in more detail below, both evaluators also administered all simulator checkrides.

Perform preflight briefing. Prior to the aircraft checkride, the subjects were given a thorough briefing on the purpose of the research and the tasks they would be required to perform. Because the subjects taught students to perform the maneuvers of interest on a daily basis, it was assumed that the subjects were knowledgeable about the procedures and techniques required to execute the maneuvers successfully. Therefore, the subjects were not required to study the ETM procedures and techniques prior to data collection, nor were they tested on their knowledge of ETM procedures and techniques.

Evaluate performance in the aircraft. The aircraft checkrides conducted in the AH-1F averaged approximately 50 minutes in length. All aircraft checkrides were conducted during daylight hours and during periods when the weather was fair and the winds were light. Each subject performed one iteration of each maneuver during the checkride. To control

for potential bias resulting from the order in which the maneuvers were performed, the order in which subjects performed the maneuvers was counterbalanced across subjects in accordance with a partial Latin Square. The evaluator occupied the CPG station (front seat) and the subject occupied the pilot station (rear seat). Each evaluator used the same aircraft to perform all of the checkrides.

All eight maneuvers investigated are maneuvers performed in the event of various inflight emergencies. The successful performance of such maneuvers is dependent upon the aircraft's position, speed, and trim at the time the maneuver is commenced. To control for this source of potential variability, the evaluators "set up" the aircraft in a manner prescribed for each maneuver prior to relinquishing control to the subject. For each maneuver, the prescribed "set up" conditions were defined in terms of altitude, lateral alignment with the runway, range from the runway, aircraft speed, aircraft attitude, and aircraft trim (see Appendix A). For each maneuver, the evaluators attempted to ensure that all conditions were the same at the time each subject assumed control of the aircraft.

To the extent commensurate with safety and evaluator workload, the evaluator completed the descriptive scales on the checklist during each maneuver. The descriptive scales that could not be completed during the maneuver were completed as soon as the aircraft landed at the end of the maneuver. The evaluator reviewed his entries on the descriptive scales and assigned an OPR for the maneuver prior to takeoff for the next maneuver.

Evaluate performance in the simulator. Subjects were scheduled for their simulator checkride as soon as possible after they had completed their aircraft checkride. In most cases, subjects completed their simulator checkride the day following their aircraft checkride. As in the aircraft checkrides, subjects performed one iteration of each target maneuver. The maneuvers were performed in the simulator in the same order that the subject performed the maneuvers in the aircraft.

An initial condition (IC) set, defined for each maneuver, served to position the simulated aircraft at a prescribed location relative to the runway and to set all aircraft flight parameters to the prescribed values. The IC sets were established to duplicate as closely as possible the conditions that existed at the time the evaluators relinquished aircraft control to the subjects during the aircraft checkrides. The IC sets were used for all simulator trials, so every subject commenced every iteration of each maneuver in the simulator under precisely the same conditions.

Both evaluators observed and evaluated all maneuvers performed in the flight simulator. One evaluator occupied the console operator station in the pilot cockpit. He operated the simulator and evaluated the subjects' performance. The second evaluator occupied the CPG station and was responsible for monitoring the flight controls and flight parameters. Both evaluators completed separate gradeslips for each maneuver. After completing a maneuver, the evaluators collaborated to derive a single set of ratings for data analysis. The collaboration included discussions between the evaluators, reference to the gradeslips they completed individually, and observation of as many maneuver replays as necessary to reach a consensus grade. Subjects were disconnected from the intercom system while the evaluators discussed performance assessment. Because of the collaboration between evaluators and the use of the simulator's replay to assess performance, a simulator checkride generally required about twice as much time (average 110 minutes) as an aircraft checkride.

Conduct posttest interviews. Each subject was interviewed immediately upon completion of the simulator checkride. The primary objective of the interviews was to assess the subjects' opinions about differences between the aircraft and the simulator that may have affected their performance. Subjects were questioned systematically about their performance and the problems they encountered on each maneuver. Each interview was recorded and subsequently transcribed. The transcripts were used to identify and tabulate reported differences between the flight simulator and the aircraft.

Results

OPR Distributions

To simplify the analyses, the OPR scale was converted to a scale ranging from 1 to 13, with 1 verbally anchored to "Unsat," 7 to "Average AQC IP," and 13 to "Excellent." The bipolar scale employed during the rating process required that the evaluators think in terms of deviations from the performance expected of the average AQC IP. However, the scale conversion was deemed necessary for data analysis and ease of reporting the data.

The frequency distributions of OPRs (collapsed across subjects and maneuvers) for performance in the AH-1F and the AH1FWS are presented in Table 4. The distribution of ratings received in the aircraft is bimodal; one mode occurs at a rating of "1" and the second mode occurs at a rating of "5." In contrast, the distribution of ratings of performance in the flight simulator is positively skewed and has a single

Table 4

Frequency Distributions of OPRs Received in the AH-1F Aircraft and AH1FWS

Performance Rating	Aircraft *f*	Aircraft Cumulative Percentage	Flight Simulator *f*	Flight Simulator Cumulative Percentage
1	23	18.0	105	82.0
2	5	21.9	0	82.0
3	6	26.6	1	82.8
4	10	34.4	4	85.9
5	22	51.6	6	90.6
6	18	65.6	0	90.6
7	16	78.1	8	96.9
8	10	85.9	1	97.6
9	4	89.1	0	97.6
10	10	96.9	2	99.2
11	0	96.9	1	100.0
12	4	100.0	0	100.0
13	0	100.0	0	100.0

mode that occurs at a rating of "1." In fact, 82% (105 of 128 ratings) of the maneuvers performed in the AH1FWS were rated as "Unsat."

Of the 23 maneuvers performed in the aircraft that were rated as "Unsat," 18 were attributed to the pilot exceeding ATM standards. Only four of the aircraft trials required SIP assistance, and there was only one instance in which a subject missed the runway. None of the maneuvers performed in the aircraft resulted in a crash. In contrast, of the 105 maneuvers performed in the flight simulator that resulted in "Unsat" ratings, 56 terminated in a crash and 25 terminated short of the runway. Only 34 of the maneuvers performed in the flight simulator were rated as "Unsat" only because the pilot exceeded ATM standards. In other words, most (68%) of the "Unsat" ratings in the flight simulator were because the subjects were not able to accomplish safe simulator landings. The subjects, did, in fact, find it extremely difficult to perform ETMs in the flight simulator.

Flight Maneuvers Analysis

Table 5 shows the mean OPR on each flight maneuver for the aircraft trials and the flight simulator trials. For

Table 5

Mean OPRs Collapsed Across Subjects for AH-1F and AH1FWS

Maneuver	AH-1F *M*	AH-1F *SD*	AH1FWS *M*	AH1FWS *SD*	*t*(15)
Shallow Approach to a Running Landing	7.2	2.45	4.5	3.15	2.80*
SCAS Off Flight	6.4	2.42	2.2	2.22	6.20**
Standard Autorotation	6.3	3.41	1.0	0.00	6.25**
Manual Throttle Operation	5.0	3.28	1.0	0.00	4.88**
Simulated Dual Hydraulic Systems Failure	4.9	2.56	1.8	1.83	3.80**
Low Level High Speed Autorotation	4.9	3.28	1.3	1.00	4.54**
Low Level Autorotation	4.5	2.36	1.6	1.63	3.81**
Simulated Right Antitorque Failure	3.9	3.09	2.4	3.31	n.s.

Note. AH1FWS = AH-1 Flight and Weapons Simulator.
 *p<.05
**p<.01

every ETM, the mean OPRs for the simulator trials were lower than the corresponding mean OPRs for the aircraft trials. As indicated in Table 5, the differences were statistically significant for seven maneuvers and not significant for one, the Simulated Right Antitorque Failure maneuver. Furthermore, the differences observed between performance in the simulator and in the aircraft were not a product of a small number of erratic subjects. Although there were a few instances in which a subject received a higher overall rating for his performance in the flight simulator than in the aircraft (7 of 128 trials), no subject received consistently higher ratings in the flight simulator than in the aircraft.

Evaluator Analysis

To detect differences in evaluations provided by the two evaluators, the OPRs awarded in the aircraft were submitted to a two-factor, mixed design analysis of variance (Evaluator X Maneuver) (Winer, 1971). This analysis indicated that, for the maneuvers performed in the aircraft, no significant difference existed between the OPRs awarded by Evaluator 1 (E1; M = 5.2, SD = 3.50) and those awarded by Evaluator 2 (E2; M = 5.5, SD = 2.61). Similarly, there was no main effect between maneuvers on the mean OPRs. There was a significant interaction between the evaluator providing the OPRs and the type of maneuver evaluated [F (7.99) = 5.31, p <.001]. However, Tukey's (1953) Honestly Significant

Difference (HSD) tests (p <.05) did not reveal significant differences in comparisons of the OPRs awarded by the two evaluators for the same maneuver.

Posttest Interview Results

The transcripts of the interviews conducted immediately after the simulator checkride were used to tabulate the type and frequency of factors that adversely affected performance in the flight simulator. The results of the posttest interview tabulations are summarized in Table 6.

In general, the aviators attributed their difficulties in the flight simulator to a lack of visual cues and inadequate fidelity in the simulated control inputs and control responses. In addition, 6 subjects reported that symptoms of nausea, faintness, and discomfort contributed to their poor performance during their simulator checkride. Four of the 6 subjects reported experiencing relatively minor symptoms; the other 2 subjects required a period to recuperate before continuing the simulator checkride.

Discussion

The results reported above indicate a low degree of backward transfer for the eight ETMs investigated in this experiment. The low degree of backward transfer is evidence that a number of deficiencies exist in the AH1FWS, particularly within the visual system and the flight controls handling and response characteristics. Accordingly, the AH1FWS and the AH-1F appear to require different flight psychophysical and perceptual skills for the successful performance of these ETMs. That is, the subjects could not successfully apply the same skills in the AH1FWS that they employ in flying the AH-1F. Furthermore, the backward transfer data indicate that, relative to their performance in the aircraft, experienced pilots exhibit significant performance decrements on some training tasks when those tasks are performed in the AH1FWS.

These data do not indicate the full extent of differences between the simulator and the aircraft, nor do they provide an estimate of the effect that the simulator deficiencies may have on the transfer of training from the AH1FWS to the AH-1F. The research findings provide evidence that AH1FWS deficiencies may affect the utility of training conducted in that device. The specific nature of these deficiencies need to be identified through psychophysical and other types of research. The impact of these deficiencies needs to be quantified through forward transfer-of-training research. This research also is necessary to support the design of training programs that will effectively and efficiently employ the AH1FWS for training operational aviators.

Table 6

Summary of Posttest Interview Comments

Percentage of Subjects Responding (N = 16)	Comment
100.0	Visual screens blurred when near ground
93.8	Unable to perceive altitude accurately when near the ground
87.5	Insufficient visual cues to maintain position during hover
81.2	Entry points difficult to judge for most maneuvers
75.0	The simulator and aircraft collective systems reacted differently to similar inputs
68.8	Peripheral vision not effective in the AH1FWS
62.5	Nose of the simulated aircraft pitched up excessively during autorotation
50.0	The simulator did not provide appropriate proprioceptive and kinesthetic cues
37.5	Experienced nausea, faintness, or discomfort
25.0	The flight simulator exhibited inappropriate heading changes in response to throttle changes during antitorque malfunctions
18.8	Vibrations in the seat shaker not realistic
12.5	Tendency to drift left while concentrating on scene in left window

EXPERIMENT 2: SIMULATOR SKILL ACQUISITION

Introduction

The results from the preliminary backward transfer experiment raised a number of questions concerning the effectiveness of the AH1FWS for training operational aviators. To address these concerns, a team of ARIARDA and Anacapa Sciences, Inc. (ASI) personnel conducted additional research using the production model AH1FWS. The objectives of the research were:

- determine the level of proficiency that operational aviators can attain on selected tasks in the AH1FWS,
- determine the amount of simulator training required for operational aviators to reach proficiency on selected tasks in the AH1FWS, and
- expand the training effectiveness data base to include routine (non-emergency) maneuvers.

The skill acquisition research was conducted at both AH1FWS training sites in the U. S. Army, Europe (USAREUR) command, (Fleigorhorst Army Airfield and Illesheim Army Airfield). At that time, USAREUR doctrine required all AH-1 units to incorporate the AH1FWS into their flight training programs. Accordingly, each unit scheduled simulator training approximately once every five weeks. This arrangement permitted the systematic selection of test subjects as the aviators reported for their scheduled training sessions. The procedures and results of the research are presented in the following subsections.

Method

Subjects

Forty aviators were selected from U. S. Army AH-1 attack battalions in the Federal Republic of Germany. All subjects were qualified and current in the AH-1F aircraft. Also, the AH1FWS had been in operation at both Fleigorhorst and Illesheim for several months prior to the research, and almost all of the potential subjects had some experience in the simulator. The only available aviators with no simulator experience were those few who had recently been assigned to USAREUR. Therefore, the 40 aviators who possessed the least AH1FWS experience (range = 0 - 84 hours) were selected as subjects.

Subjects were assigned to four groups of 10 aviators each, according to the week that their unit was scheduled for

training in the simulator. Table 7 presents flight experience information for the subjects in each of the four groups, and Table 8 presents the highest AH-1F qualification rating held by each of the subjects in each group. The subject assignment procedures resulted in groups that were not equal in terms of previous flight experience. As can be seen in Table 7, the four groups varied in both the mean number of total flight hours and the mean number of hours previously flown in the AH-1F aircraft.

Due to resource restrictions and the research team's commitment to conduct other research during the same time period, 27 subjects were tested at the Fleigorhorst simulator facility and 13 subjects were tested at the Illesheim simulator facility. All of the subjects in Groups 1 and 2, and 7 of the subjects in Group 4, were tested at Fleigorhorst. All of the subjects in Group 3, and 3 of the subjects in Group 4, were tested at Illesheim.

Evaluators

All evaluators were AH-1 SIPs assigned to the USAREUR Aviation Safety and Standardization Board (UASSB). Their normal duties included performing flight evaluations and providing expert assistance to the operational aviators who participated in training sessions conducted in the AH1FWS. Two SIPs were trained by the researchers, and they performed all of the evaluations at the Illesheim simulator site. However, during the test period, SIPs at the Fleigorhorst facility were not relieved of their normal duties. Therefore, four SIPs were trained as evaluators at Fleigorhorst to ensure that two trained evaluators were present during each data collection period.

Equipment

All performance data were collected in two production model AH1FWS, one located at Fleigorhorst and the other at Illesheim. This device is described fully in the AH-1 Operator's Manual (Department of the Army, 1984a) and is similar to the prototype AH1FWS used during the backward transfer research reported in Experiment 1 with two notable exceptions. The motion system of the production model simulator has 60-inch legs, instead of the 45-inch legs installed on the prototype model; its visual system utilizes laser image generation techniques instead of the camera model system. The laser image generation system employs a multicolored laser beam that scans a high detail, three-dimensional terrain modelboard. The modelboard provides a gaming area of approximately 7.3 kilometers by 19.5 kilometers on a scale of 1:1000. Scattered, reflected light is detected by a bank of photomultiplier tubes. The outputs from all of the photomultiplier tubes are combined to produce

Table 7

Previous Simulator and Aircraft Flight Hour Experience (Mean and Range)

Group	Total Hours	AH-1F Hours	AH1FWS Hours	UH1FS Hours
Group 1 (n=10)	1100 (320-5500)	623 (200-2200)	16.2 (4-50)	68.8 (20-160)
Group 2 (n=10	533 (295-1150)	369 (130-1000)	23.7 (8-84)	61.2 (32-125)
Group 3 (n=10)	437 (212-910)	235 (70-600)	14.4 (6-35)	42.5 (20-80)
Group 4 (n=10)	919 (222-3225)	331 (46-1400)	18.2 (0-78)	116.2 (35-250)

Note. AH1FWS = AH-1 Flight and Weapons Simulator; UH1FS = UH-1 Flight Simulator.

Table 8

Highest Current Qualification in the AH-1F Aircraft

Rating	Group 1	Group 2	Group 3	Group 4
Pilot	3	3	6	7
Pilot in Command	6	6	3	2
Unit Trainer	0	1	1	1
Instructor Pilot	1	0	0	0

a composite video signal as the system gantry follows the flight path of the simulated aircraft.

Maneuvers

Fifteen maneuvers were selected for investigation in this research. Eight of the maneuvers were the same ETMs investigated in Experiment 1. Seven tactical, nap-of-the-earth (NOE) and standard contact maneuvers were added for this investigation. A complete description of each of the

maneuvers is presented in Appendix A. Performance was measured on 15 maneuvers in the pilot station and 5 selected maneuvers in the CPG station.

Each of the four groups of subjects was tested on a different set of maneuvers; Table 9 presents the maneuvers performed by each group. To ensure that a complete data set was obtained for as many maneuvers as possible, each group of 10 subjects was tested on one group of five maneuvers before the next group of 10 subjects was tested on the next group of five maneuvers.

Table 9

Maneuvers Performed by Each Group

Group 1 (Pilot Station)	Group 2 (Pilot Station)
Vertical Helicopter IMC Recovery Procedures	Hovering Tasks
Standard Autorotation	Stabilization Control Augmentation System Off Flight
Terrain Flight Approach	Normal Approach to a Pinnacle
Simulated Right Antitorque Failure	Low Level High Speed Autorotation
Unmasking/Firing/Masking	Shallow Approach to a Running Landing
Group 3 (Pilot Station)	**Group 4 (CPG Station)**
Terrain Flight Takeoff	Hovering Tasks
Low Level Autorotation	Standard Autorotation
Manual Throttle Operation	Low Level Autorotation
Simulated Dual Hydraulic Systems Failure	Normal Approach (to Stagefield)
NOE Acceleration/Deceleration	Shallow Approach to a Running Landing

Note. IMC = Instrument Meteorological Conditions; NOE = Nap-of-the-Earth.

Performance Measures

The gradeslips that were developed and used during the Backward Transfer Experiment were modified and used in this experiment. In addition, seven additional gradeslips were developed for the seven additional maneuvers. The additional gradeslips retained the bipolar 13-point rating scale format for rating each of the important parameters in each maneuver.

The bipolar 13-point format also was retained for rating the overall performance during execution of the maneuvers. Because of the different subject population in this experiment, the OPR scale was modified to reflect a different criterion for satisfactory performance. The subject population consisted of AH-1F aviators who were qualified to fly as Pilot in Command (PIC) during operational missions. Therefore, the OPR scale was modified so that the ratings would reflect the evaluators' expectations of performance for the average PIC. Figure 4 depicts the modified OPR scale. Appendix B presents each of the 15 gradeslips used during this experiment.

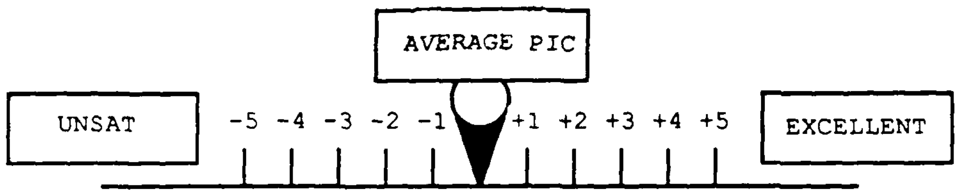

Figure 4. Bipolar 13-point OPR scale for Experiment 2.

Evaluator Training

Evaluator training was conducted during the week prior to the beginning of data collection. The evaluators were briefed on the maneuvers of interest, the gradeslips, the performance criteria, and the evaluation procedures. For the remainder of the week, the evaluators practiced using the gradeslips while evaluating aviator performance in the AH1FWS. Extensive use of the replay capability featured in the AH1FWS helped ensure accurate and consistent evaluations.

Data Collection Procedures

Each subject participated in the research for five consecutive days (Monday through Friday). During the five days, each aviator completed 10 trials on each of the five maneuvers in the AH1FWS. The researchers restricted the number of trials to 10 for each maneuver to standardize the amount of simulator training received by each subject. It was assumed that 10 trials would be sufficient for most aviators to reach a level of proficiency in the AH1FWS equivalent to their proficiency in the AH-1F aircraft.

On Day 1, the subjects completed a checkride in the AH1FWS that comprised one iteration of each of the five maneuvers. Following the checkride on Day 1, the subjects completed nine practice trials of Maneuver 1. On Days 2 through 5, each subject performed nine practice trials of

Maneuvers 2 - 5 (one maneuver per day) until 10 iterations of all five maneuvers were completed in the AH1FWS. The subjects maintained a counterbalanced order of maneuvers (partial Latin Square) across the checkrides and all training trials.

The procedures employed to assess aviator performance were similar to those used in the AH1FWS during Experiment 1. Two SIPs evaluated all maneuvers performed in the AH1FWS. One evaluator occupied the console operator station in the pilot's cockpit. The second evaluator occupied the CPG station for Groups 1, 2, and 3 and the pilot station for Group 4. During each trial, both evaluators recorded the subject's performance on the descriptive scales of the appropriate gradeslip. After completing each trial, the subject's intercom system was disconnected while the evaluators discussed each segment of the maneuver to arrive at a consensus description and overall rating of the subject's performance. During this discussion, the evaluators employed the playback feature of the AH1FWS as often as necessary to ensure the accuracy of the data that they had recorded.

After the evaluators concluded their discussions, the subject's intercom system was reconnected and the AH1FWS was initialized to begin the next trial of the maneuver. The subjects received no instruction or feedback about their performance during the first three trials of a maneuver (including the checkride). During trials 4 through 10, however, the evaluators provided instruction to each subject in an effort to improve the subject's performance as quickly as possible. This instruction was provided by one evaluator after the consensus evaluations had been completed and while the other evaluator initialized the AH1FWS.

Results

The OPRs provided by the evaluators served as the principal dependent measure in the analyses of skill acquisition. The results of these analyses are presented below.

A One-Way ANOVA (Winer, 1971) with repeated measures across the 10 trials was performed on the OPRs for each maneuver. These analyses are summarized in Table 10 (pilot station) and Table 11 (CPG station). All significant differences revealed by the ANOVAs were in the positive direction and were interpreted as evidence that significant learning had occurred for those maneuvers. Under this interpretation, the significant F ratios in Table 10 and Table 11 identify the 11 specific maneuvers in which significant learning occurred. Significant changes in the mean OPRs across trials were not found for the following four maneuvers:

Table 10

Summary of Analyses of Skill Acquisition in the AH1FWS - Pilot Maneuvers

Pilot Maneuvers	F (9, 81)	Trials to Significant Improvement
Terrain Flight Takeoff	6.44**	2
VHIRP	2.41*	5
NOE Acceleration/Deceleration	6.30**	2
Shallow Approach to a Running Landing	7.52**	4
Terrain Flight Approach	3.71**	6
Simulated Dual Hydraulic Systems Failure	4.87**	5
Simulated Right Antitorque Failure	n.s.	
Hovering Tasks	3.30**	6
SCAS Off Flight	2.77**	6
Low Level Autorotation	5.06**	4
Unmasking/Firing/Masking	4.24**	7
Manual Throttle Operation	16.57**	4
Normal Approach to a Pinnacle	4.33**	6
Standard Autorotation	n.s.	
Low Level High Speed Autorotation	n.s.	

Note. AH1FWS = AH-1 Flight and Weapons Simulator; VHIRP = Vertical Helicopter Instrument Meteorological Conditions Recovery Procedures; NOE = Nap-of-the-Earth; SCAS = Stabilization Control Augmentation System.
*p<.05
**p<.01

- Simulated Right Antitorque Failure (Pilot),
- Standard Autorotation (Pilot),
- Low Level High Speed Autorotation (Pilot), and
- Low Level Autorotation (CPG).

It should be noted that, although there was no significant change across trials of the Low Level Autorotation maneuver when performed in the CPG station, there was a significant change across trials for the maneuver in the pilot station.

Table 11

Summary of Analyses of Skill Acquisition in the AH1FWS - Copilot/Gunner Maneuvers

Copilot/Gunner Maneuvers	F (9, 81)	Trials to Significant Improvement
Standard Autorotation	3.41**	7
Low Level Autorotation	n.s.	
Hovering Tasks	3.33**	6
Shallow Approach to a Running Landing	2.11**	5
Normal Approach to a Stagefield	3.19**	5

*$p<.05$
**$p<.01$

Tukey's (1953) HSD tests were used to determine the trial on which significant improvements in performance first These data also are included in Table 10 (pilot) and Table 11 (Copilot/Gunner) in the column in each table that is labeled "Trials to Significant Improvement." Although no significant learning occurred for the Low Level Autorotation maneuver after 10 trials in the CPG station, significant learning did occur for the maneuver after four trials in the pilot station. Significant learning occurred for two pilot maneuvers (Terrain Flight Takeoff and NOE Acceleration/Deceleration) prior to any instruction or feedback provided by the evaluators.

The benefits of instruction provided subsequent to Trial 3 were manifested in significant learning effects on Trials 4 and 5 for the following seven maneuvers:

- VHIRP (Pilot),
- Shallow Approach to a Running Landing (Pilot),
- Simulated Dual Hydraulic Systems Failure (Pilot),
- Low Level Autorotation (Pilot),
- Manual Throttle Operation (Pilot),
- Shallow Approach to a Running Landing (CPG), and

- Normal Approach to Stagefield (CPG).

For these maneuvers, the instruction apparently alleviated problems contributing to poor performance during the first three trials. These problems may have included deficiencies in the aviators' techniques and/or in the unique design characteristics of the AH1FWS.

The mean OPR for each maneuver was plotted across trials to produce a learning curve. The learning curves are presented in Appendix C. The mean OPRs reached a level of 7 ("Average PIC") within the 10 practice trials for only three maneuvers: Terrain Flight Takeoff (9 trials), VHIRP (7 trials), and Manual Throttle Operation (9 trials). That is, the operational aviators were able to reach the same level of proficiency in the AH1FWS as the evaluators expected them to exhibit in the AH-1F on only three maneuvers.

A linear regression was fitted to the data for each maneuver on which there were significant learning effects. Predictions of the number of trials required for the mean OPR to reach 7 were produced from the regression equations. The predictions and the proportions of variance accounted for by the regression models are presented in Tables 12 and 13. The predictions for the number of trials to reach a mean OPR of 7 range from 9 trials for Manual Throttle Operation (pilot station) to 28 trials for Hovering Tasks (CPG station).

Discussion

Although operational units train aviators to be proficient in the aircraft, not the simulator, the skill acquisition data serve two important functions. First, they provide an indirect indication of the types of AH1FWS training that may transfer to the AH-1F. Second, the skill acquisition data indicate that if operational units intend to conduct mission or tactical training in the AH1FWS, they first must train the aviators to fly the AH1FWS. Simulator-specific training requires substantial time and instruction.

The assumption that most of the subjects would reach proficient levels of performance in the AH1FWS within 10 practice trials was not supported by the skill acquisition data. In fact, the average proficiency rating reached a level of 7 for only 3 of the 20 maneuvers. The estimated number of trials for operational aviators to reach the same level of proficiency in the AH1FWS that the SIPs expected of them in the aircraft suggest that considerable training time is required for aviators to become proficient simulator pilots.

Table 12

Summary of Predicted Trials to Attain an OPR of 7 - Pilot Station

Pilot Task	Predicted Trials	r^2
Terrain Flight Takeoff	10	.84
VHIRP	10	.62
NOE Acceleration/Deceleration	14	.86
Shallow Approach to a Running Landing	11	.86
Terrain Flight Approach	14	.58
Simulated Dual Hydraulic Systems Failure	14	.84
Simulated Right Antitorque Failure	--	--
Hovering Tasks	17	.66
SCAS Off Flight	25	.67
Low Level Autorotation	16	.62
Unmasking/Firing/Masking	12	.84
Manual Throttle Operation	9	.93
Normal Approach to Pinnacle	17	.86
Standard Autorotation	--	--
Low Level High Speed Autorotation	--	--

Note. OPR = Overall Performance Rating; VHIRP = Vertical Helicopter Instrument Meteorological Conditions Recovery Procedures; NOE = Nap-of-the-Earth; SCAS = Stabilization Control Augmentation System; -- = no significant improvement shown over 10 trials.

Table 13

Summary of Predicted Trials to Attain an OPR of 7 - Copilot/Gunner Station

Pilot Task	Predicted Trials	r^2
Standard Autorotation	22	.84
Low Level Autorotation	--	--
Hovering Tasks	28	.90
Shallow Approach to a Running Landing	20	.78
Normal Approach to Pinnacle	18	.74

Note. OPR = Overall Performance Rating; -- = no significant improvement shown over 10 trials.

The rapid learning observed for the Terrain Flight Takeoff and NOE Acceleration/Deceleration maneuvers indicates good simulator fidelity for these maneuvers. It also indicates that the subjects adapted their aircraft flying

skills in performing these maneuvers to the AH1FWS. The significant learning that occurred within 10 trials on all but four of the remaining maneuvers is evidence that the subjects adapted their flight skills on these maneuvers to the AH1FWS after some practice and instruction. The four maneuvers are ETMs. As discussed earlier, the subjects are prohibited from practicing these maneuvers in the aircraft and thus cannot be considered proficient. Their poor performance in the flight simulator may reflect either the subjects' lack of experience in performing these maneuvers or a system deficiency in the AH1FWS.

Additionally, these data suggest that the simulation of these maneuvers may be inadequate and that it may not be feasible to conduct training on these maneuvers in the AH1FWS. However, it is possible that, given additional practice, the aviators' performance might have improved.

The results from the skill acquisition research also may have been confounded by the inability to match the experimental groups based upon the subjects' previous flight experience. Highly experienced aviators may acquire skill in the AH1FWS at a different rate than less experienced aviators. No data were obtained to indicate the degree to which this factor affected pilot performance in the AH1FWS.

GENERAL DISCUSSION

The Army has acquired and fielded the AH1FWS without concurrently developing empirically based training strategies that effectively incorporate the AH1FWS into aviator training programs. Little data currently exist to indicate the extent to which training conducted in the AH1FWS affects performance in the AH-1F. Consequently, after the simulators are installed at various sites, the development of training programs and utilization of the devices become the responsibility of individual unit commanders. In the absence of other information or instructions, unit aviators and trainers conduct training in the AH1FWS simulator in the same way that they conduct training in the aircraft.

The two experiments reported above represent the initial steps in the comprehensive research program designed to evaluate the effectiveness and utility of the AH1FWS for training aviators assigned to operational units. The experiments also provide part of the data base required to design programs of instruction that address specific training needs of operational aviators. The implications of these experiments are discussed below in the following order:

- Backward Transfer Research
- Performance Measurement
- Diagnostic Research
- Conclusions
- Recommendations

Backward Transfer Research

Backward transfer research may identify maneuvers that can be trained effectively in the simulator and should, therefore, be targeted for forward transfer research. In addition, backward transfer research may provide important information about how to conduct and evaluate research on the maneuvers of interest. That is, they provide a testbed for developing appropriate procedures before actually conducting complex transfer-of-training experiments. The backward transfer approach may be most valuable when addressing the effectiveness of flight simulators for skill sustainment training.

[illegible] to which backward transfer research can identify [illegible] maneuvers that should be subjected to forward [illegible] research needs to be determined empirically. Based

upon the results of these two experiments, the effectiveness of the AH1FWS is predicted to be low or negative for training ETMs and moderate to high for training Terrain Flight Takeoff and Manual Throttle Operation Maneuvers. Nevertheless, proficiency in performing ETMs is important enough to warrant conducting research to investigate the forward transfer of ETM training from the AH1FWS to the AH-1F aircraft. ARIARDA currently is planning to conduct such research.

Performance Measurement

The two experiments reported here employed the same 13-point OPR scale except that the two scales were anchored to the expected performance of two different subject populations. In both cases, the scales were sensitive to variability in satisfactory aviators' performance, but were insensitive to variability when the aviators' performance was below established standards. Only one point on the scale (Unsat) was considered unsatisfactory performance. Therefore, the OPRs did not distinguish between deficiencies merely rated as unsatisfactory and other deficiencies that resulted in catastrophic failures.

Furthermore, the majority of the trials did not meet established standards and, therefore, received the UNSAT rating. This was particularly evident in the skill acquisition experiment, where OPR scales did not possess the sensitivity required to indicate improvements in performance prior to reaching a satisfactory level. The learning curves developed from these data and reported in Appendix C also did not indicate the learning that occurred prior to reaching a satisfactory level of performance.

Prior to conducting future research, the OPR scale should be revised to provide a better distinction between satisfactory and unsatisfactory performance and to indicate performance variability within both ranges. Optimally, a revised scale will allow evaluators to record (a) performance improvements as aviators learn to perform maneuvers, and (b) performance variability over time as aviators sustain their skills on selected maneuvers.

Diagnostic Research

No flight simulator will ever replicate the aircraft environment perfectly; however, the training effectiveness of flight simulators will be enhanced if simulators function optimally. For example, aviators reported that their inability to judge altitude and range accurately contributed to their poor performance on certain flight tasks in the AH1FWS.

Diagnostic research should be conducted to investigate further characteristics of the simulator systems that contribute to poor aviator performance. For example, one line of research should investigate the aspects of the visual system that result in poor depth perception. Such research may identify relatively low cost adjustments or modifications that may alleviate the depth perception problem and enhance training conducted in the AH1FWS. Such research also may contribute to the design requirements of future flight simulators.

Conclusions

In conclusion, the backward transfer experiment (Experiment 1) and the skill acquisition experiment (Experiment 2) have demonstrated that significant differences exist between the AH-1F aircraft and the AH1FWS. The two should not be considered as interchangeable training devices for the 15 pilot station maneuvers and the 5 CPG station maneuvers investigated in this research. The AH1FWS may provide an inadequate simulation of the AH-1F aircraft because backward transfer was low when using either the camera model system or the laser image generation visual system. In general, the aviators attributed their performance deficiencies to insufficient visual and motion cues provided by the AH1FWS and to deficiencies in the AH1FWS' control handling and aerodynamic response characteristics.

The regression analyses of the skill acquisition data indicate that qualified and current AH-1 aviators require significant amounts of training (estimated average of 14 practice trials per pilot station maneuver) to acquire proficient flight skills in the AH1FWS. Prior to conducting any meaningful unit mission training, a significant amount of time and resources may be required to train qualified and current AH-1 aviators to fly the AH1FWS.

Recommendations

Four recommendations can be drawn from the preceding discussion. These include:

- conduct skill acquisition and transfer-of-training research designed to evaluate the training effectiveness and utility of the AH1FWS,

- revise the OPR scale so that it is more sensitive to performance below proficiency standards,

- conduct research to determine the predictive validity of the backward transfer paradigm, and

- conduct research designed to identify the components of the AH1FWS that contribute to poor aviator performance.

Pending the completion of this additional research, the AH1FWS should be used with caution when training operational unit aviators on the maneuvers investigated in these two experiments.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AAA	-	Army Audit Agency
AGL	-	Above Ground Level
AH1FWS	-	AH-1 Flight and Weapons Simulator
AH64CMS	-	AH-64 Combat Mission Simulator
AMC	-	Army Materiel Command
ANOVA	-	Analysis of Variance
AQC	-	Aircrew Qualification Course
ARIARDA	-	Army Research Institute Aviation Research and Development Activity
ASI	-	Anacapa Sciences, Inc.
ATM	-	Aircrew Training Manual
CH47FS	-	CH-47 Flight Simulator
CPG	-	Copilot/Gunner
DA	-	Department of the Army
DARCOM	-	Development and Readiness Command
DES	-	Directorate of Evaluation and Standardization
DOTD	-	Directorate of Training and Doctrine
E1	-	Evaluator 1
E2	-	Evaluator 2
ETM	-	Emergency Touchdown Maneuver
FRG	-	Federal Republic of Germany
HL	-	Helicopter Length
HSD	-	Honestly Significant Difference
IC	-	Initial Condition
IMC	-	Instrument Meteorological Conditions
IP	-	Instructor Pilot
IPC	-	Instructor Pilot Course
KIAS	-	Knots Indicated Airspeed
LLA	-	Low Level Autorotation
LLHSA	-	Low Level High Speed Autorotation
MTO	-	Manual Throttle Operation
NOE	-	Nap-of-the-Earth
OPR	-	Overall Performance Rating
PIC	-	Pilot in Command
POI	-	Program of Instruction
RPM	-	Revolutions Per minute
PPDR	-	Pilot Performance Description Record
SA	-	Standard Autorotation
SARL	-	Shallow Approach to a Running Landing
SCAS	-	Stabilization Control Augmentation System
SFTS	-	Synthetic Flight Training System
SHF	-	Simulated Dual Hydraulics Systems Failure
SIP	-	Standardization Instructor Pilot
TRADOC	-	Training and Doctrine Command
SME	-	Subject Matter Expert
SRAF	-	Simulated Right Antitorque Failure
UASSB	-	USAREUR Aviation Safety and Standardization Board

GLOSSARY OF ACRONYMS AND ABBREVIATIONS - Continued

UH1FS	-	UH-1 Flight Simulator
UH60FS	-	UH-60 Flight Simulator
USAAVNC	-	U. S. Army Aviation Center
USAREUR	-	U. S. Army, Europe
VHIRP	-	Vertical Helicopter IMC Recovery Procedures

APPENDIX A

DESCRIPTION OF MANEUVERS INVESTIGATED

Fifteen maneuvers were investigated in the two research experiments presented in this report. A description of each of these maneuvers is presented in this appendix. The following eight maneuvers were investigated in both the backward transfer experiment (Experiment 1) and the skill acquisition experiment (Experiment 2).

- Standard Autorotation,
- Low Level Autorotation,
- Simulated Dual Hydraulic Systems Failure,
- Simulated Right Antitorque Failure,
- Low Level High Speed Autorotation,
- Shallow Approach to a Running Landing,
- Manual Throttle Operation, and
- Stabilization Control Augmentation System (SCAS) Off Flight.

The following seven maneuvers were investigated only in Experiment 2.

- Hovering Tasks,
- Nap-of-the-Earth Acceleration/Deceleration,
- Normal Approach,
- Terrain Flight Approach,
- Terrain Flight Takeoff,
- Unmasking/Firing/Masking, and
- Vertical Helicopter Instrument Meteorological Conditions Recovery Procedures.

During Experiment 2, five maneuvers were investigated in both the pilot station and the CPG station. These five maneuvers were:

- Hovering Tasks,
- Low Level Autorotation,
- Normal Approach,
- Shallow Approach to a Running Landing, and
- Standard Autorotation.

With the exception of Normal Approach, the maneuvers attempted in the two crewstations were identical. The differences between the Normal Approach maneuver performed in the CPG station and the one performed in the pilot station are described in the section of the appendix entitled, Normal Approach (ATM Tasks 1028 and 2004).

Hovering Tasks (ATM Task 1017)

The Hovering Tasks maneuver was performed as described in Task 1017 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls, the subjects executed, in order, (a) a takeoff to a 3-foot hover, (b) a 90° right pedal turn, (c) a 90° left pedal turn back to the runway heading, (d) a hovering taxi down the runway's center line to a designated point, and (e) a landing from a 3-foot hover.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject:

- Position in gaming area = the approach end of the stagefield runway,
- Altitude = 0 feet above ground level (AGL)
- Airspeed = 0 knots indicated airspeed (KIAS), and
- Heading = aligned with runway approach heading.

Low Level Autorotation (ATM Task 3002)

The Low Level Autorotation maneuver was performed as described in Task 3002 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls on a long final approach to the stagefield, the subjects maintained the specified airspeed, heading, and altitude until the aircraft reached a point from where they could terminate a Low Level Autorotation on the stagefield. The subjects then initiated

the Low Level Autorotation and continued the maneuver to the ground.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = 2-mile final approach to the stagefield,
- Altitude = 100 feet above the highest obstacle when the subject took the flight controls,
- Airspeed = 100 KIAS, and
- Heading = aligned with runway approach heading.

Low Level High Speed Autorotation (ATM Task 3005)

The Low Level High Speed Autorotation maneuver was performed as described in Task 3005 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls on a long final approach to the stagefield, the subjects maintained the specified airspeed, heading, and altitude until the aircraft reached a point from where they could terminate a Low Level Autorotation on the stagefield. The subjects then initiated the Low Level High Speed Autorotation and continued the maneuver to the ground.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = 2-mile final approach to the stagefield,
- Altitude = 100 feet above the highest obstacle when the subject took the flight controls,
- Airspeed = 130 KIAS, and
- Heading = aligned with runway approach heading.

Manual Throttle Operation (ATM Task 1056)

The Manual Throttle Operation maneuver was performed as described in Task 1056 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls, the subjects activated the emergency governor mode and executed, in order, (a) a takeoff to a 3-foot hover, (b) a 90° right pedal turn, (c) a 90° left pedal turn back to the runway heading, and (d)

a landing from a hover. The evaluators instructed the subjects that they could take as much time as necessary to execute a safe and well controlled maneuver.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = the approach end of the stagefield runway,
- Altitude = 0 feet AGL,
- Airspeed = 0 KIAS, and
- Heading = aligned with runway approach heading.

NOE Acceleration/Deceleration (ATM Task 1037)

The NOE Acceleration/Deceleration maneuver was performed as described in Task 1037 of the AH-1 ATM (Department of the Army, 1984b), with several modifications. The subjects took control of the AH1FWS while masked behind a treeline at a stationary hover. They were required to unmask, accelerate to 50 KIAS while remaining at NOE altitude, and then decelerate to arrive at a stationary hover over a small bridge. The entire course was a straight line approximately two kilometers in length traversing both wooded and open terrain. Prior to their first trial, all subjects observed a prerecorded demonstration of the NOE route to identify significant landmarks.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject:

- Position in gaming area = masked behind a treeline,
- Altitude = 20 feet AGL,
- Airspeed = 0 KIAS, and
- Heading = aligned with heading of the NOE route.

Normal Approach (ATM Tasks 1028 and 2004)

The Normal Approach maneuver was performed by one group of subjects in the pilot station and by another group of subjects in the CPG station. The maneuver differed for the two groups; subjects in the pilot station performed a normal

approach to a pinnacle, and subjects in the CPG station performed a normal approach to a stagefield. Therefore, this maneuver combined elements of ATM tasks 1028 (VMC Approach) and 2004 (Pinnacle Operation) (Department of the Army, 1984b). Subjects attempting the maneuver in the CPG station took the flight controls on a long final approach to the stagefield, initiated the normal approach at their discretion, and executed a landing on the stagefield. Subjects attempting the maneuver in the pilot station took the flight controls on a long final approach to a pinnacle, initiated the normal approach at their discretion, and executed a landing in a confined area on the pinnacle.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject attempting the maneuver in the pilot station:

- Position in gaming area = 1-mile final approach to the pinnacle,

- Altitude = 500 feet AGL at the confined area on a pinnacle,

- Airspeed = 80 KIAS, and

- Heading = aligned with the approach into the confined area on the pinnacle.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject attempting the maneuver in the CPG station:

- Position in gaming area = 2-mile final approach to the stagefield,

- Altitude = 500 feet AGL,

- Airspeed = 80 KIAS, and

- Heading = aligned with runway approach heading.

Stabilization Control Augmentation System (SCAS) Off Flight (ATM Task 1059)

The Stabilization Control Augmentation System (SCAS) Off Flight maneuver was performed as described in task 1059 of the AH-1 ATM (Department of the Army, 1984b). Performance standards for this maneuver also were taken from AH-1 ATM tasks 1022 (Traffic Pattern Flight) and 1028 (VMC Approach). After taking the flight controls on the downwind leg of the

stagefield traffic pattern, the subjects stabilized the heading, airspeed, and altitude at the specified values, disengaged all channels of SCAS, completed the traffic pattern, and executed a normal approach and landing on the stagefield.

The evaluator established the following parameters in the AH1FWS and the AH-1F on each trial prior to relinquishing the flight controls to the subject:

- Position in gaming area = downwind leg of the stage-field traffic pattern,
- Altitude = 800 feet AGL at a stagefield,
- Airspeed = 100 KIAS, and
- Heading = aligned with reciprocal of the runway approach heading.

Shallow Approach to a Running Landing (ATM Task 1030)

The Shallow Approach to a Running Landing maneuver was performed as described in Task 1030 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls on a long final approach, the subjects initiated a *shallow approach* at their discretion and completed a running landing to the stagefield.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = 2-mile final approach to the stagefield,
- Altitude = 500 feet AGL at the stagefield,
- Airspeed = 100 KIAS, and
- Heading = aligned with runway approach heading.

Simulated Dual Hydraulic Systems Failure (ATM Task 3003)

The Simulated Dual Hydraulic Systems Failure maneuver was simulated in the AH-1F by engaging the aircraft force trim as described in task 3003 of the AH-1 ATM (Department of the Army, 1984b). However, the AH1FWS simulated a complete dual hydraulic systems failure. In both the AH1FWS and the AH-1F, the subjects stabilized the heading, altitude, and airspeed at the specified values after taking the flight controls on

the downwind leg of the traffic pattern. The evaluator then inserted the malfunction by activating the force trim in the AH-1F or by inserting malfunction number 653 (Dual Hydraulics Failure) in the AH1FWS. The subjects were required to complete the traffic pattern and execute a normal approach and landing at the stagefield. Prior to attempting their first trial, all subjects observed a demonstration of the stagefield traffic pattern to identify significant landmarks.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = downwind leg of the stage-field traffic pattern,
- Altitude = 800 feet AGL at the stagefield,
- Airspeed = 100 KIAS, and
- Heading = aligned with reciprocal of the runway approach heading.

Simulated Right Antitorque Failure (ATM Task 3004)

The Simulated Right Antitorque Failure maneuver was performed as described in task 3004 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls on a long final approach, the subjects stabilized the heading, airspeed, and altitude at the specified values and then applied up to one ball width of right pedal, not to exceed 10° of aircraft heading. At that time, the evaluator fixed the pitch by locking the pedals in the AH-1F or by inserting malfunction number 755 (Tail Rotor Fixed Pitch) in the AH1FWS. The subjects were required to complete the approach and execute a landing at the stagefield.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = 2-mile final approach to stagefield,
- Altitude = 500 feet AGL at the stagefield,
- Airspeed = 80 KIAS, and
- Heading = aligned with runway approach heading.

Standard Autorotation (ATM Task 3001)

The Standard Autorotation maneuver was performed as described in task 3001 of the AH-1 ATM (Department of the Army, 1984b). After taking the flight controls on a long final approach to the stagefield, the subjects maintained the specified airspeed, heading, and altitude until the aircraft reached a point from where they could terminate a Standard Autorotation on the stagefield. The subjects than initiated the Standard Autorotation and continued the maneuver to the ground.

On each trial, the evaluator established the following parameters in the AH1FWS and the AH-1F prior to relinquishing the flight controls to the subject:

- Position in gaming area = 2-mile final approach to the stagefield,
- Altitude = 800 feet AGL at the stagefield,
- Airspeed = 100 KIAS, and
- Heading = aligned with runway approach heading.

Terrain Flight Approach (ATM Task 1038)

The Terrain Flight Approach maneuver combined elements of three AH-1 ATM tasks (Department of the Army, 1984b), including 1038 (Terrain Flight Approach), 1035 (Terrain Flight), and 1031 (Confined Area Operations). Subjects took the flight controls while the AH1FWS was in a stationary hover at NOE altitude, flew a specified NOE course approximately one kilometer in length, and executed an approach and a landing in a confined area. The evaluator served as navigator and copilot throughout the terrain flight portion of the maneuver to ensure that the subject found the confined area.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject:

- Position in gaming area = above a stream bed approximately one kilometer from a confined landing area,
- Altitude = 20 feet AGL,
- Airspeed = 0 KIAS, and

- Heading = aligned with desired initial direction of the NOE flight.

Terrain Flight Takeoff (ATM Task 1034)

The Terrain Flight Takeoff maneuver combined elements of three tasks in the AH-1 ATM (Department of the Army, 1984b), including 1034 (Terrain Flight Takeoff), 1035 (Terrain Flight), and 1031 (Confined Area Operations). Subjects took the flight controls while the AH1FWS was positioned on the ground in a confined landing area. They executed a terrain flight takeoff out of the confined area, transitioned to an NOE flight mode, and flew at NOE altitude on a designated course approximately one kilometer in length. The evaluator served as navigator and copilot throughout the terrain flight portion of the maneuver.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject:

- Position in gaming area = in a confined landing area,
- Altitude = 0 feet AGL,
- Airspeed = 0 KIAS, and
- Heading = aligned with desired initial direction of the NOE flight after takeoff.

Unmasking/Firing/Masking (ATM Task 1090)

The Unmasking/Firing/Masking maneuver was performed as described in task 1090 of the AH-1 ATM (Department of the Army, 1984b), with several modifications. Subjects were given a target handover by the evaluator. After taking the flight controls, the subjects (a) stabilized the AH1FWS, (b) configured the cockpit switches consistent with the target handover, (c) unmasked vertically, (d) acquired the targets, (e) fired four pairs of rockets, and (f) remasked to a stationary hover.

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject:

- Position in gaming area = masked behind a treeline approximately 1200 meters from a target array of three tanks in a straight line,

- Altitude = 20 feet AGL,
- Airspeed = 0 KIAS,
- Heading = aligned with target array located at heading of 360°, and
- Weapons configuration = 1.

Vertical Helicopter Instrument Meteorological Conditions Recovery Procedures (ATM Task 1083)

The Vertical Helicopter Instrument Meteorological Conditions (IMC) Recovery Procedures (VHIRP) maneuver was performed as described in task 1083 of the AH-1 ATM (Department of the Army, 1984b). The subjects took the flight controls with the AH1FWS in a normal flight mode and executed turns as directed by the evaluator. At their discretion, the evaluators required the subjects to execute the VHIRP maneuver by reducing visibility to zero. To prevent the subjects from anticipating when to initiate the VHIRP, the evaluators varied the point where the AH1FWS entered the IMC across trials .

On each trial, the evaluator established the following parameters in the AH1FWS prior to relinquishing the flight controls to the subject:

- Position in gaming area = varied across trials,
- Altitude = 500 feet AGL,
- Airspeed = 100 KIAS, and
- Heading = aligned with desired heading of flight.

APPENDIX B

GRADESLIPS USED FOR MANEUVERS INVESTIGATED IN THE SKILL ACQUISITION EXPERIMENT

This appendix contains the gradeslips used to measure performance on the 15 maneuvers evaluated during the skill acquisition experiment (Experiment 2). The gradeslips follow the same format that was developed and used for grading the eight maneuvers in the backward transfer experiment (Experiment 1). The first part of the gradeslip is a series of scales that provide detailed information about performance during each phase of the maneuver. A bipolar 13-point rating scale, anchored to the appropriate standard and tolerance, was constructed for most of the performance parameters. The second part of the gradeslip is a bipolar 13-point rating scale for recording overall performance on the maneuver. In Experiment 2, the overall performance standard was anchored to the Average PIC. In Experiment 1, the standard was anchored to the average AQC IP.

CONTENTS

STANDARD AUTOROTATION

ID#: ______________________ TRIAL: ________

COACHING: [ ] Yes [ ] No

FRONT SEAT [X] BACK SEAT [ ]

COMMENTS

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ENTRY	AIRSPEED	SLOW	10	8	6	4	2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	100	80	60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TECHNIQUE	YES	NO										
DESCENT	ROTOR RPM	LOW	CORRECT	HIGH									
	AIRSPEED	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
DECELERATION	AIRSPEED AT 100 FEET	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
	ALTITUDE	LOW	-15	-12	-9	-6	-3	+3	+6	+9	+12	+15	HIGH
	AMOUNT	LITTLE	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	MUCH
PITCH/PULL	INITIAL ALTITUDE	LOW	5	6	7	8	9	16	17	18	19	20	HIGH
	INITIAL AMOUNT	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	TECHNIQUE	SLOW	5	4	3	2	1	1	2	3	4	5	ABRUPT
	HEADING	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
TOUCHDOWN	TOUCHDOWN ATTITUDE	LEVEL	5	4	3	2	1	1	2	3	4	5	TAIL SKID
	CUSHION	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	LANDING	HARD	5	4	3	2	1						
	GROUND SLIDE	MUCH	5	4	3	2	1						
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	EXCELLENT

AVERAGE PIC

LOW LEVEL AUTOROTATION

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [X] BACK SEAT [ ]

COMMENTS

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

ENTRY	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TECHNIQUE	YES	NO										
DESCENT	ROTOR RPM	LOW	CORRECT	HIGH									
	AIRSPEED	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
DECELERATION	AIRSPEED AT 100 FEET	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
	ALTITUDE	LOW	-15	-12	-9	-6	-3	+3	+6	+9	+12	+15	HIGH
	AMOUNT	LITTLE	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	MUCH
PITCH/PULL	INITIAL ALTITUDE	LOW	5	6	7	8	9	16	17	18	19	20	HIGH
	INITIAL AMOUNT	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	TECHNIQUE	SLOW	5	4	3	2	1	1	2	3	4	5	ABRUPT
	HEADING	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
TOUCHDOWN	TOUCHDOWN ATTITUDE	LEVEL	5	4	3	2	1	1	2	3	4	5	TAIL SKID
	CUSHION	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	LANDING	HARD	5	4	3	2	1						
	GROUND SLIDE	MUCH	5	4	3	2	1						
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT

SIMULATED DUAL HYDRAULIC SYSTEMS FAILURE

ID#: ____________ TRIAL: ____

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

DOWNWIND	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TRIM	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
TURN FINAL	CONSTANT BANK	SHALLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	STEEP
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	TRIM	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
APPROACH	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
	CONSTANT APPROACH ANGLE	SHALLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	STEEP
	AIRSPEED	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
TOUCHDOWN	AIRSPEED	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
	HEADING	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
	LANDING	HARD	5	4	3	2	1						
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT

SIMULATED RIGHT ANTITORQUE FAILURE

ID#: ______________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

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OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

ENTRY	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
APPROACH	ANGLE	STEEP	5	4	3	2	1						
	RATE OF CLIMB	SLOW	5	4	3	2	1	1	2	3	4	5	FAST
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
THREE FEET	TOUCHDOWN POINT	SHORT	5	4	3	2	1	1	2	3	4	5	LONG
	AIRSPEED	SLOW	5	4	3	2	1	1	2	3	4	5	FAST
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
TOUCHDOWN	COLLECTIVE	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	THROTTLE REDUCTION	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	LANDING	HARD	5	4	3	2	1						
	HEADING ON TOUCHDOWN	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
	HEADING ON SLIDE	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT

SHALLOW APPROACH TO A RUNNING LANDING

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [X] BACK SEAT [ ]

COMMENTS

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OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

ENTRY	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
	ANGLE	STEEP	5	4	3	2	1						
APPROACH	CONSTANT APPROACH ANGLE	SHALLOW	5	4	3	2	1	1	2	3	4	5	STEEP
	RATE OF CLIMB	SLOW	5	4	3	2	1	1	2	3	4	5	FAST
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
TOUCHDOWN	AIRSPEED	SLOW	5	4	3	2	1	1	2	3	4	5	FAST
	HEADING	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
	LANDING	HARD	5	4	3	2	1						
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT

LOW LEVEL HIGH SPEED AUTOROTATION

ID#: ______________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

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____

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

ENTRY	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TECHNIQUE	YES	NO										
DESCENT	ROTOR RPM	LOW	CORRECT	HIGH									
	AIRSPEED	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
DECELERATION	AIRSPEED	SLOW	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	FAST
	AT 100 FEET ALTITUDE	LOW	-15	-12	-9	-6	-3	+3	+6	+9	+12	+15	HIGH
	AMOUNT	LITTLE	-5	-4	-3	-2	-1	+1	+2	+3	+4	+5	MUCH
PITCH/PULL	INITIAL ALTITUDE	LOW	5	6	7	8	9	16	17	18	19	20	HIGH
	INITIAL AMOUNT	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	TECHNIQUE	SLOW	5	4	3	2	1	1	2	3	4	5	ABRUPT
	HEADING	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
TOUCHDOWN	TOUCHDOWN ATTITUDE	LEVEL	5	4	3	2	1	1	2	3	4	5	TAIL SKID
	CUSHION	LITTLE	5	4	3	2	1	1	2	3	4	5	MUCH
	LANDING	HARD	5	4	3	2	1						
	GROUND SLIDE	MUCH	5	4	3	2	1						
	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT

MANUAL THROTTLE OPERATION

ID#: ____________ TRIAL: ____

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

TAKEOFF

DRIFTS	EXCESSIVE	5	4	3	2	1							
ALTITUDE	LOW	-2.5	-2.0	-1.5	-1.0	-.5	+.5	+1.0	+1.5	+2.0	+2.5	HIGH
RPM	LOW	-2.0	-1.6	-1.2	-.8	-.4	+.4	+.8	+1.2	+1.6	+2.0	HIGH
HEADING	LEFT	10°	8°	6°	4°	2°	2°	4°	6°	8°	10°	RIGHT

LEFT TURN

DRIFTS	EXCESSIVE	5	4	3	2	1						
ALTITUDE	LOW	-2.5	-2.0	-1.5	-1.0	-.5	+.5	+1.0	+1.5	+2.0	+2.5	HIGH
RPM	LOW	-2.0	-1.6	-1.2	-.8	-.4	+.4	+.8	+1.2	+1.6	+2.0	HIGH
RATE	SLOW	5	4	3	2	1	1	2	3	4	5	FAST

RIGHT TURN

DRIFTS	EXCESSIVE	5	4	3	2	1						
ALTITUDE	LOW	-2.5	-2.0	-1.5	-1.0	-.5	+.5	+1.0	+1.5	+2.0	+2.5	HIGH
RPM	LOW	-2.0	-1.6	-1.2	-.8	-.4	+.4	+.8	+1.2	+1.6	+2.0	HIGH
RATE	SLOW	5	4	3	2	1	1	2	3	4	5	FAST

TOUCHDOWN

DRIFTS	EXCESSIVE	5	4	3	2	1						
RPM	LOW	-2.0	-1.6	-1.2	-.8	-.4	+.4	+.8	+1.2	+1.6	+2.0	HIGH
HEADING	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT

STABILIZATION CONTROL AUGMENTATION SYSTEM (SCAS) OFF FLIGHT

ID#: ______________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

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OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

DOWNWIND LEG	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	FAST
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TRIM	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
BASE LEG AND TURN	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TRIM	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
FINAL LEG AND TURN	GROUND TRACK	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
	AIRSPEED	SLOW	-10	-8	-6	-4	-2	+2	+4	+6	+8	+10	FAST
	ALTITUDE	LOW	-100	-80	-60	-40	-20	+20	+40	+60	+80	+100	HIGH
	TRIM	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
APPROACH	CONSTANT APPROACH ANGLE	SHALLOW	5	4	3	2	1	1	2	3	4	5	STEEP
	RATE OF CLOSURE	SLOW	5	4	3	2	1	1	2	3	4	5	FAST
	TRIM	LEFT	5	4	3	2	1	1	2	3	4	5	RIGHT
TOUCHDOWN	TERMINATION	SHORT	5	4	3	2	1	1	2	3	4	5	LONG
	LANDING	HARD	5	4	3	2	1						
	HEADING	LEFT	5°	4°	3°	2°	1°	1°	2°	3°	4°	5°	RIGHT
	RATE OF CLOSURE	SLOW	5	4	[illegible]	2	1	1	2	3	4	5	FAST
	CYCLIC	UNDER	5	4	3	2	1	1	2	3	4	5	OVER

HOVERING TASKS

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

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OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

TAKEOFF TO HOVER	DRIFTS	EXCESSIVE	±1'			▲				
	ALTITUDE	LOW	-1'			▲ 3'			+4'	HIGH
	HEADING	LEFT	-10°	-6°	-3°	▲	+3°	+6°	+10°	RIGHT
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER
RIGHT TURN	DRIFTS	EXCESSIVE	±2'		±1'	▲				
	ALTITUDE	LOW	-1'			▲			+1'	HIGH
	RATE	FAST	3	2	1	▲				
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER
LEFT TURN	DRIFTS	EXCESSIVE	±2"		±1'	▲				
	ALTITUDE	LOW	-1'			▲			+1'	HIGH
	RATE	FAST	3	2	1	▲				
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER
HOVERING FLIGHT	HEADING	LEFT	10°	6°	3°	▲	3°	6°	10°	RIGHT
	SPEED	SLOW	3	2	1	▲	1	2	3	FAST
	ALTITUDE	LOW	-1'			▲			+1'	HIGH
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER
LANDING FROM HOVER	DRIFTS	EXCESSIVE	±1'			▲				
	HEADING	LEFT	-10°	-6°	-3°	▲	+3°	+6°	+10°	RIGHT
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER
	TOUCHDOWN	HARD	3	2	1	▲				

NAP-OF-THE-EARTH ACCELERATION / DECELERATION

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

ACCELERATION								
CONTROL	UNDER	3	2	1	1	2	3	OVER
ALTITUDE	LOW	3	2	1	1	2	3	HIGH
PITCH ATTITUDE	LOW	3	2	1	1	2	3	HIGH
POWER	LITTLE	3	2	1	1	2	3	MUCH
HEADING	LEFT	10°	6°	3°	3°	6°	10°	RIGHT

DECELERATION								
CONTROL	UNDER	3	2	1	1	2	3	OVER
ATTITUDE	LOW	3	2	1	1	2	3	HIGH
PITCH ALTITUDE	LOW	3	2	1	1	2	3	HIGH
HEADING	LEFT	10°	6°	3°	3°	6°	10°	RIGHT
TERMINATION GROUNDSPEED	FAST	5	3	1				
TERMINATION POINT	SHORT	50'	35'	20'	20'	35'	50'	LONG

OVERALL RATING

UNSAT					AVERAGE PIC					EXCELLENT
-5	-4	-3	-2	-1		+1	+2	+3	+4	+5

NORMAL APPROACH

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [X] BACK SEAT [ ]

COMMENTS

ENTRY	ALTITUDE	LOW	-100'	-60'	-30'	▲	+30'	+60'	+100'	HIGH
	AIRSPEED	SLOW	-10K	-6K	-3K	▲	+3K	+6K	+10K	FAST
	TRIM	LEFT	3	2	1	▲	1	2	3	RIGHT
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
APPROACH	INITIAL ANGLE	SHALLOW	3	2	1	▲	1	2	3	STEEP
	TRIM	LEFT	3	2	1	▲	1	2	3	RIGHT
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
	RATE OF CLOSURE	SLOW	3	2	1	▲	1	2	3	FAST
	LINE OF DESCENT	UNDER ARC	3	2	1	▲	1	2	3	OVER ARC
TOUCHDOWN	RATE OF CLOSURE	SLOW	3	2	1	▲	1	2	3	FAST
	TERMINATION	SHORT	3	2	1	▲	1	2	3	LONG
	LANDING	HARD	3	2	1	▲				
	HEADING	LEFT	10°	6°	3°	▲	3°	6°	10°	RIGHT
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
	GROUND SLIDE	MUCH	3	2	1	▲				
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER

OVERALL RATING

UNSAT					AVERAGE PIC					EXCELLENT
-5	-4	-3	-2	-1	▼	+1	+2	+3	+4	+5

ID#: ________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

TERRAIN FLIGHT APPROACH

			3	2	1	▲	1	2	3	
TERRAIN FLIGHT	ALTITUDE	LOW	3	2	1	▲	1	2	3	HIGH
	HEADING	LEFT	10°	6°	3°	▲	3°	6°	10°	RIGHT
	TRIM	LEFT	3	2	1	▲	1	2	3	RIGHT
	DECELERATION	LITTLE	3	2	1	▲	1	2	3	MUCH
APPROACH	INITIAL ANGLE	SHALLOW	3	2	1	▲	1	2	3	STEEP
	HEADING	LEFT	3	2	1	▲	1	2	3	RIGHT
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
	RATE OF CLOSURE	SLOW	3	2	1	▲	1	2	3	FAST
	LINE OF DESCENT	UNDER ARC	3	2	1	▲	1	2	3	OVER ARC
TOUCHDOWN	RATE OF CLOSURE	SLOW	3	2	1	▲	1	2	3	FAST
	TERMINATION	SHORT	3	2	1	▲	1	2	3	LONG
	LANDING	HARD	3	2	1	▲				
	HEADING	LEFT	10°	6°	3°	▲	3°	6°	10°	RIGHT
	GROUND SLIDE	MUCH	3	2	1	▲				
	CONTROL	UNDER	3	2	1	▲	1	2	3	OVER

TERRAIN FLIGHT TAKEOFF

ID#: ____________ TRIAL: ____

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

TAKEOFF	HEADING	LEFT	10°	6°	3°	▲	3°	6°	10°	RIGHT
	POWER	LITTLE	3	2	1	▲	1	2	3	MUCH
	PITCH ATTITUDE	LOW	3	2	1	▲	1	2	3	HIGH
	ANGLE	LOW	3	2	1	▲	1	2	3	HIGH
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
TERRAIN TRANSITION	ALTITUDE	LOW	3	2	1	▲	1	2	3	HIGH
	POWER	LITTLE	3	2	1	▲	1	2	3	MUCH
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
	TAIL ALIGNMENT	LEFT	3	2	1	▲	1	2	3	RIGHT
	ACCELERATION	LITTLE	3	2	1	▲	1	2	3	MUCH
NOE FLIGHT	TAIL ALIGNMENT	LEFT	3	2	1	▲	1	2	3	RIGHT
	GROUND TRACK	LEFT	3	2	1	▲	1	2	3	RIGHT
	ALTITUDE	LOW	3	2	1	▲	1	2	3	HIGH
	GROUND SPEED	SLOW	3	2	1	▲	1	2	3	FAST

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

UNMASKING / FIRING / MASKING

UNMASK

CONTROL	UNDER	3	2	1	1	2	3	OVER
POWER APPLICATION	SLOW	3	2	1	1	2	3	FAST
POWER	LITTLE	3	2	1	1	2	3	MUCH
ALTITUDE	LOW	3	2	1	1	2	3	HIGH

ENGAGEMENT

CONTROL	UNDER	3	2	1	1	2	3	OVER
DRIFT	EXCESSIVE	3	2	1				
SWITCHOLOGY CORRECT	YES	NO						
SWITCHES SET	MASKED	UNMASKED						
TARGET AQUIRED	YES	NO						
ROCKETS FIRED	YES	NO						
EXPOSURE TIME	LONG	1	2	3				

MASKING

CONTROL	UNDER	3	2	1	1	2	3	OVER
POWER REDUCTION	SLOW	3	2	1	1	2	3	FAST
POWER	LITTLE	3	2	1	1	2	3	MUCH
FULLY MASKED	YES	NO						

OVERALL RATING

UNSAT AVERAGE PIC EXCELLENT

-5 -4 -3 -2 -1 +1 +2 +3 +4 +5

VERTICAL HELICOPTER INSTRUMENT METEOROLOGICAL CONDITIONS RECOVERY PROCEDURES

ID#: ____________ TRIAL: ______

COACHING: [ ] Yes [ ] No

FRONT SEAT [ ] BACK SEAT [X]

COMMENTS

OVERALL RATING

UNSAT	-5	-4	-3	-2	-1	AVERAGE PIC	+1	+2	+3	+4	+5	EXCELLENT

INITIATION

PITCH ATTITUDE	LOW	5°	3°	1°	▲	1°	3°	5°	HIGH
ROLL ATTITUDE	LEFT	15°	10°	5°	▲	5°	10°	15°	RIGHT
HEADING	LEFT	10°	6°	3°	▲	3°	6°	10°	RIGHT
CONTROL	UNDER	3	2	1	▲	1	2	3	OVER
AIRSPEED	SLOW	-10K	-6K	-3K	▲	+3K	+6K	+10K	FAST
POWER	LITTLE	3	2	1	▲	1	2	3	MUCH

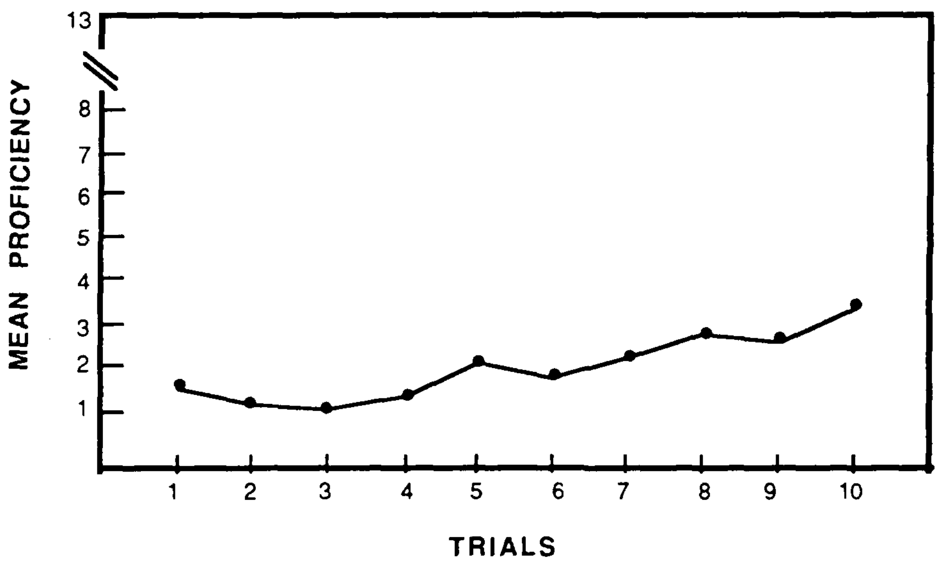
CLIMBOUT

TRIM	LEFT	3	2	1	▲	1	2	3	RIGHT
HEADING	LEFT	10°	6°	3°	▲	3°		10°	RIGHT
AIRSPEED	SLOW	-10K	-6K	-3K	▲	+3K	+6K	+10K	FAST
RATE OF CLIMB	LOW	-100	-60	-30	▲	+30	+60	+100	HIGH
ROLL ATTITUDE	LEFT	15°	10°	5°	▲	5°	10°	15°	RIGHT
PITCH ATTITUDE	LOW	5°	3°	1°	▲	1°	3°	5°	HIGH

APPENDIX C

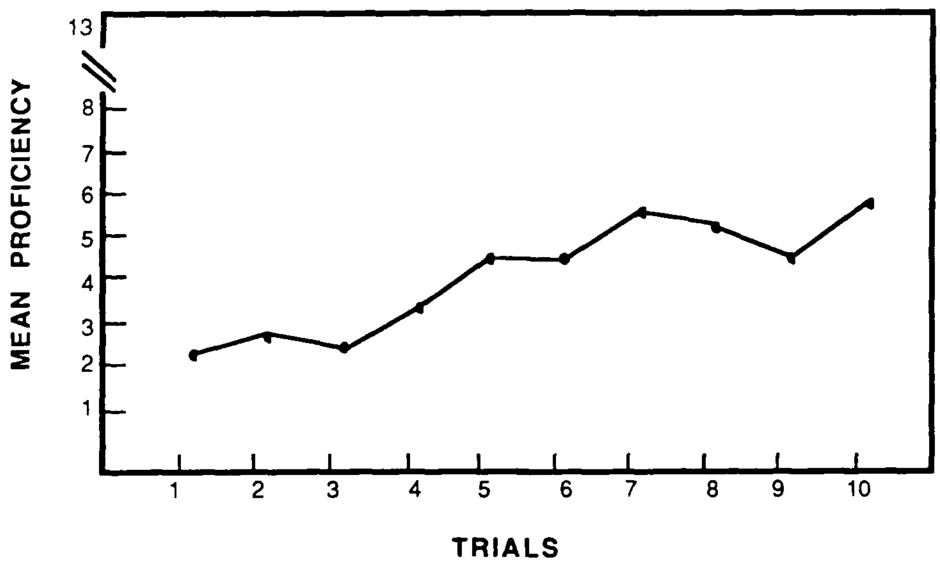
SKILL ACQUISITION DATA FOR AH1FWS

The OPRs served as the principal dependent measure in the analysis of skill acquisition. The mean OPR for each maneuver was plotted across trials to produce a learning curve. The learning curves depict the average increase in proficiency that occurred across the 10 trials for each maneuver. The learning curves are presented in this appendix.

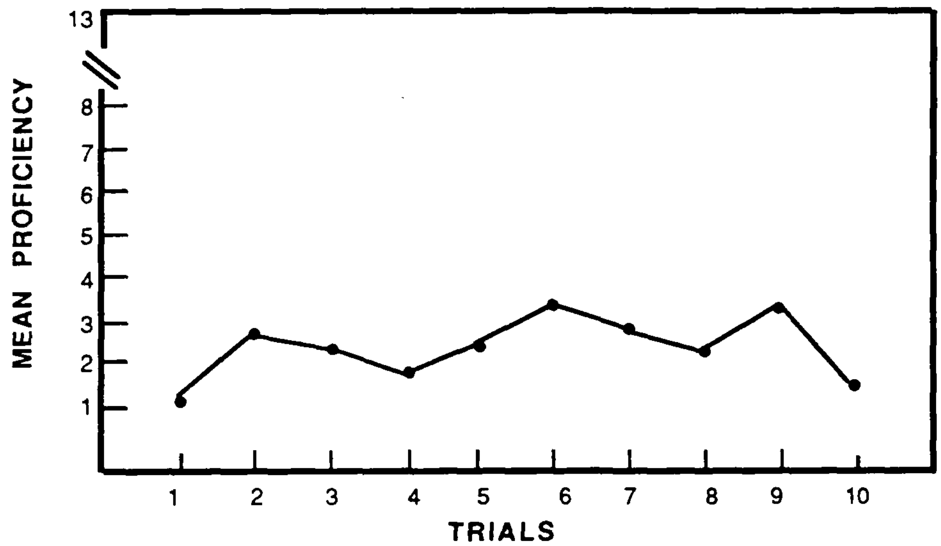


Standard Autorotation (pilot).

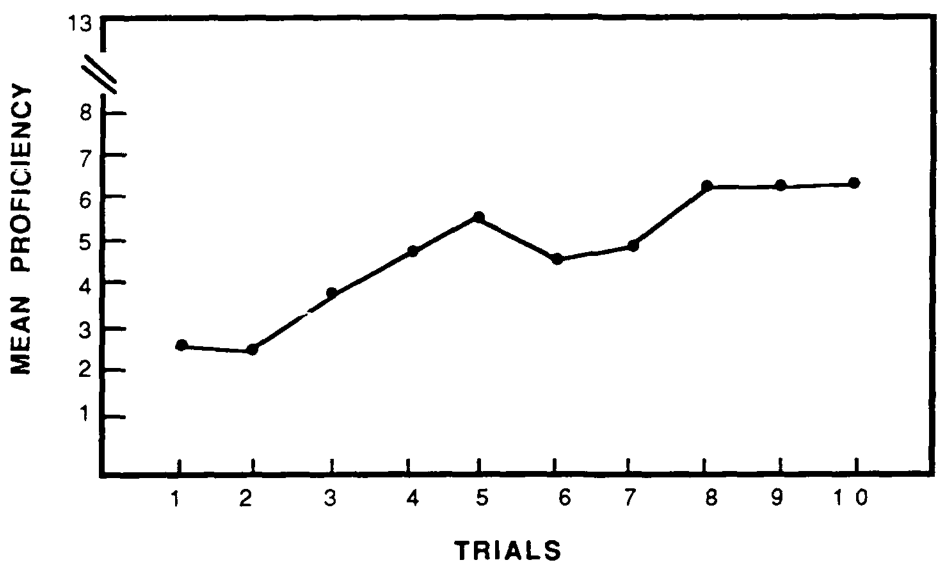
Low Level Autorotation (pilot)



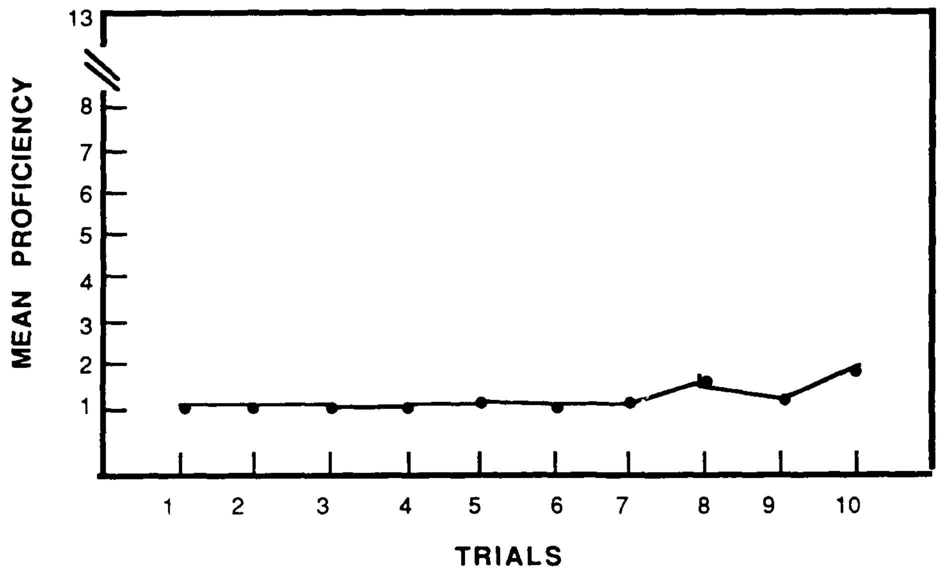
Simulated Dual Hydraulic Systems Failure
(pilot)



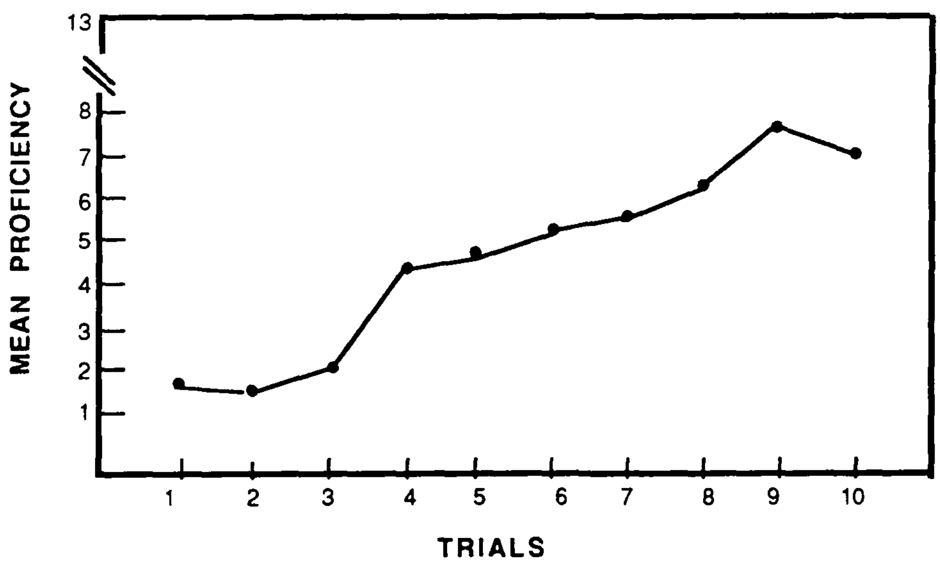
Simulated Right Antitorque Failure (pilot)



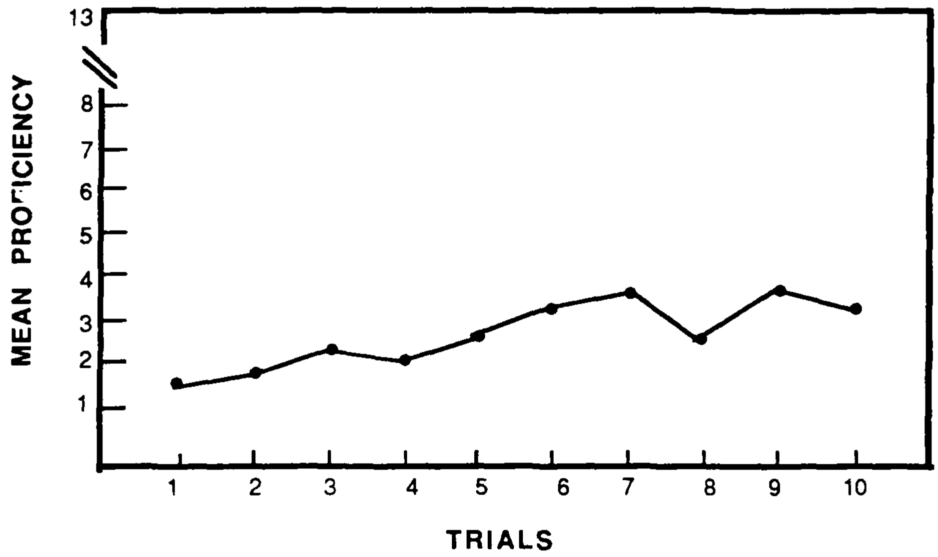
Shallow Approach to a Running Landing (pilot)



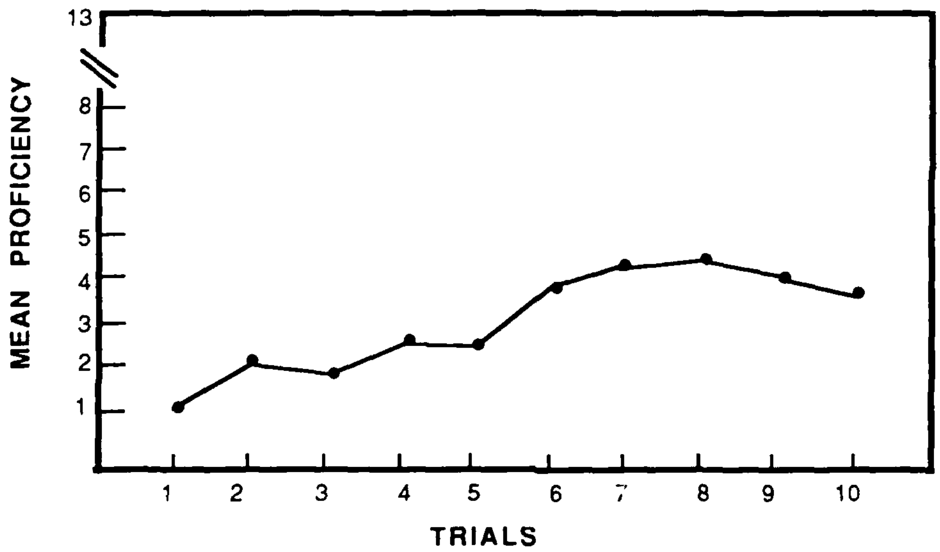
Low Level High Speed Autorotation (pilot)



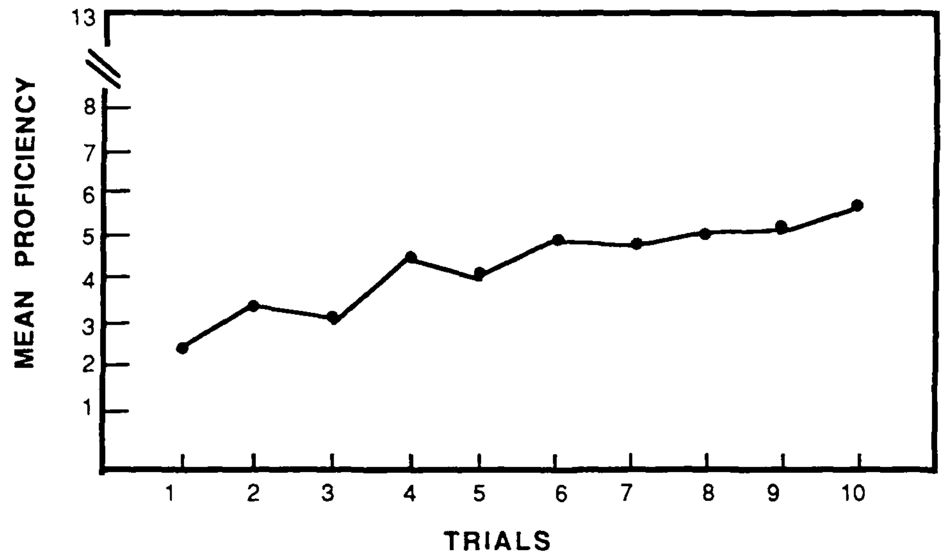
Manual Throttle Operation (pilot)



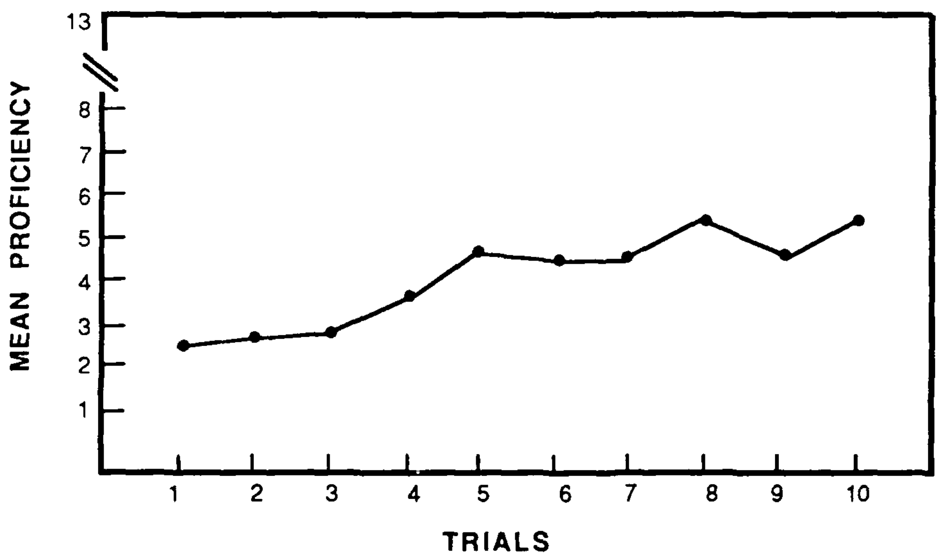
Stabilization Control Augmentation System Off
Flight (pilot)



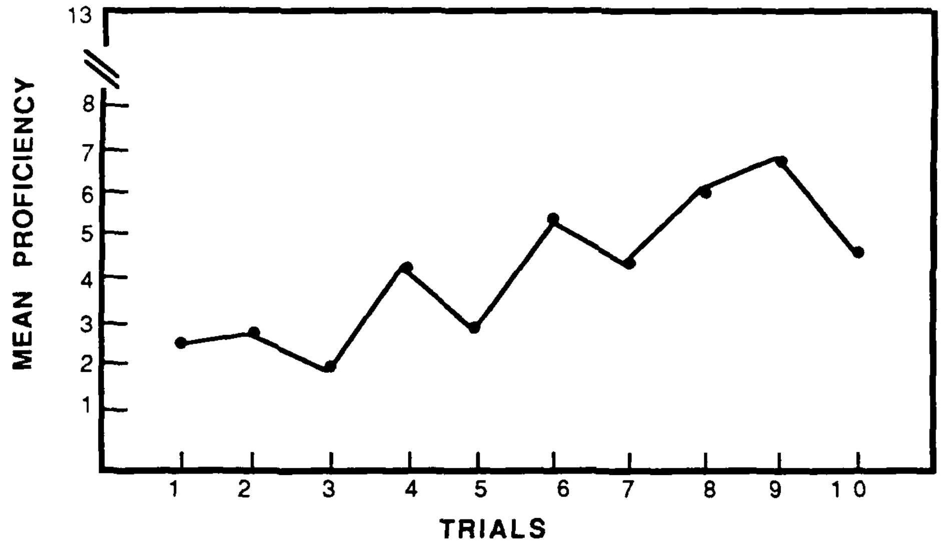
Hovering Tasks (pilot)



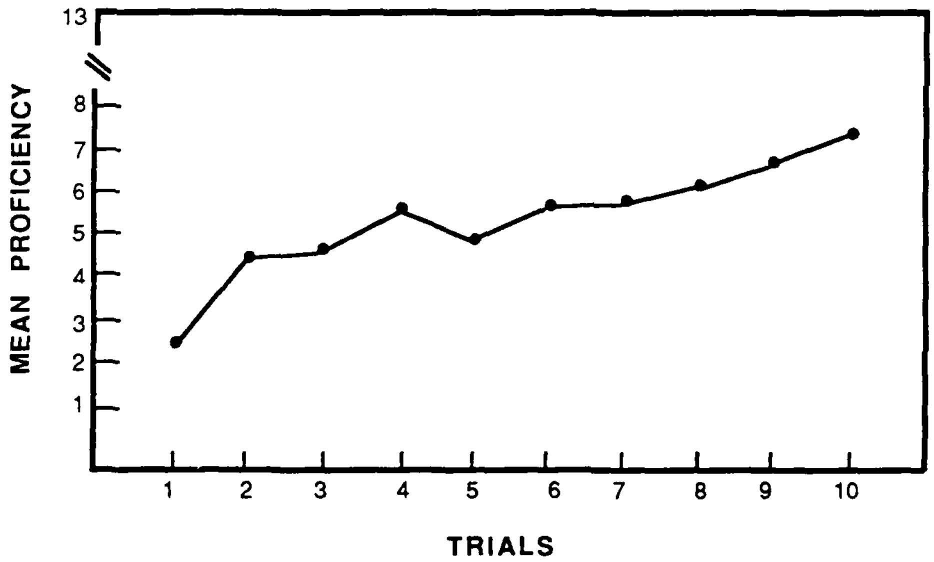
Nap-of-the-Earth Acceleration/Deceleration (pilot)



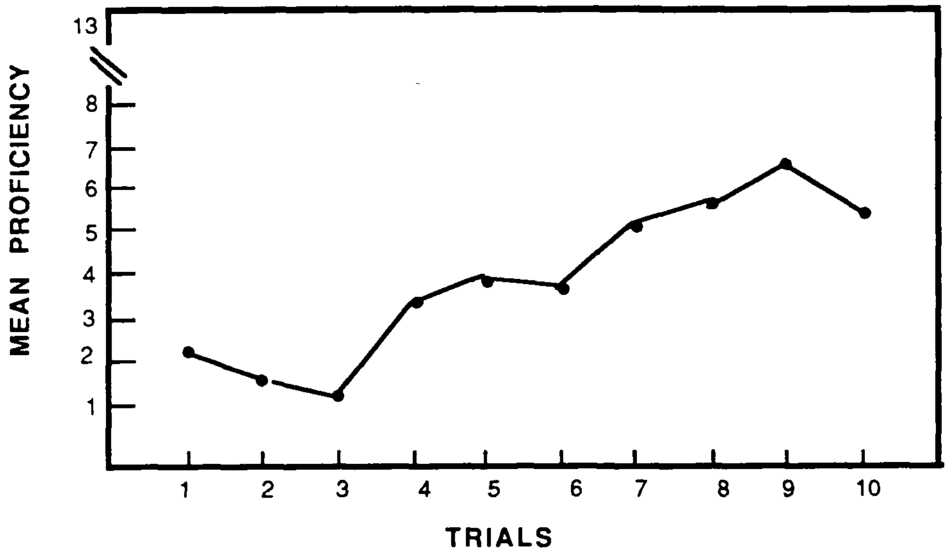
Normal Approach (pilot)



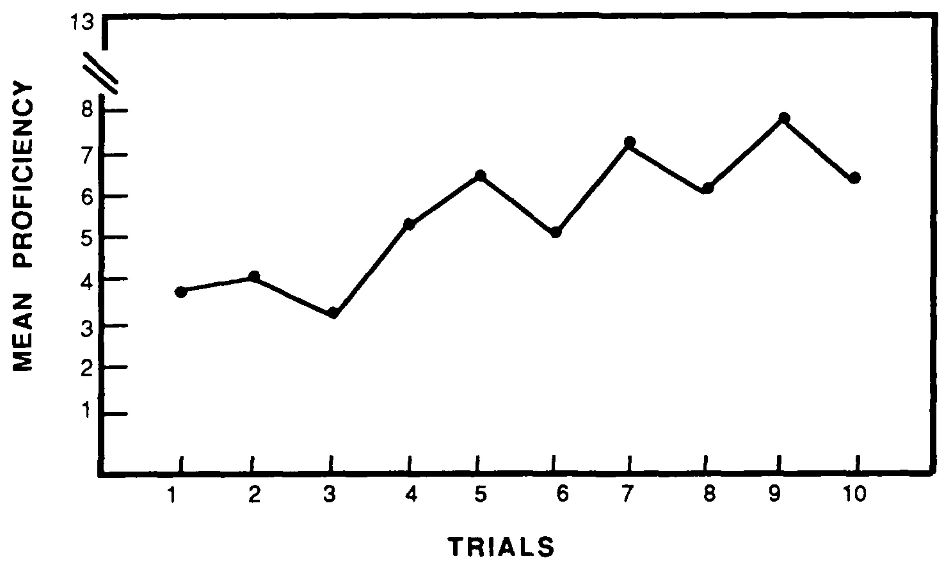
Terrain Flight Approach (pilot)



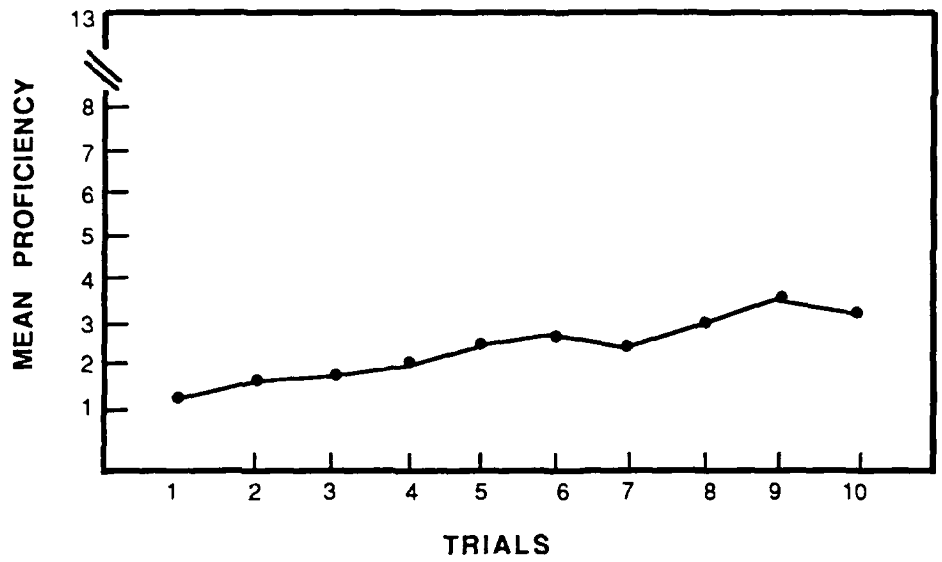
Terrain Flight Takeoff (pilot)



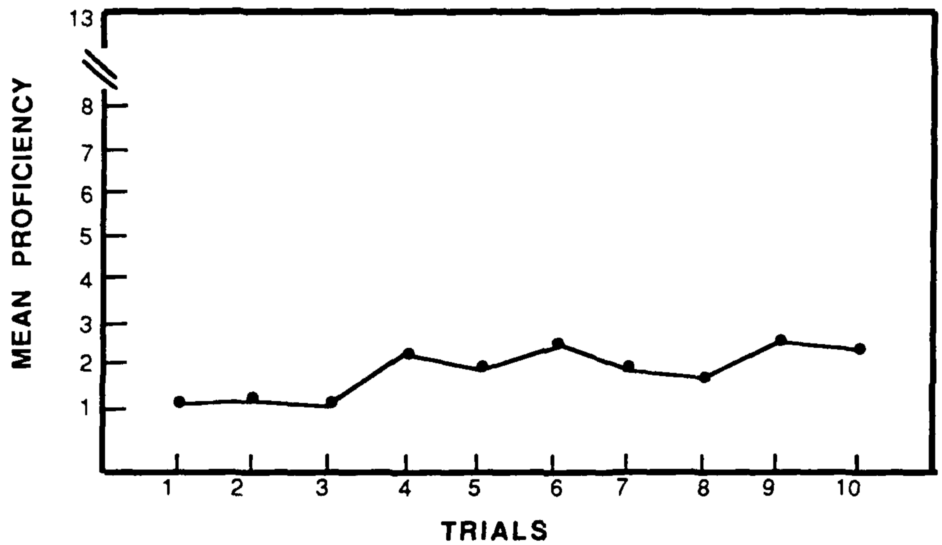
Unmasking/Firing/Masking (pilot)



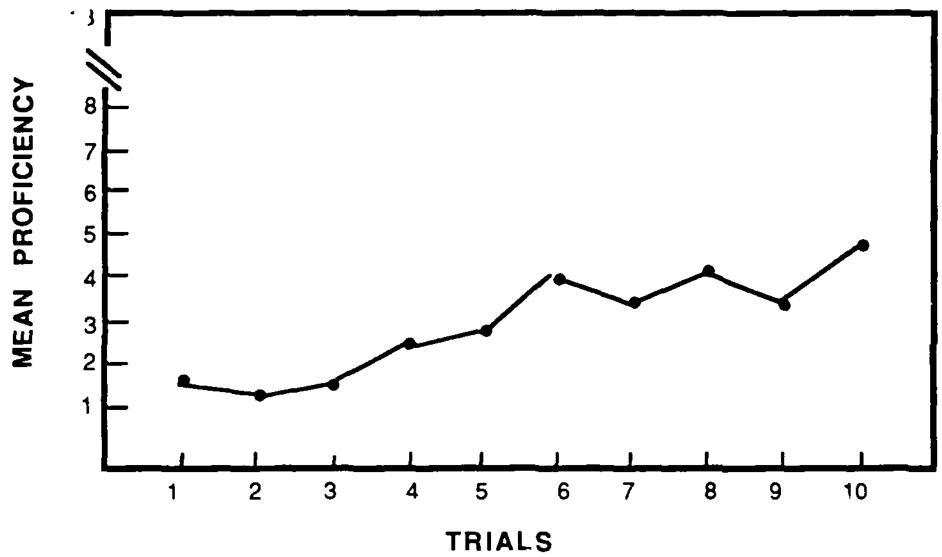
Vertical Helicopter IMC Recovery Procedures (pilot)



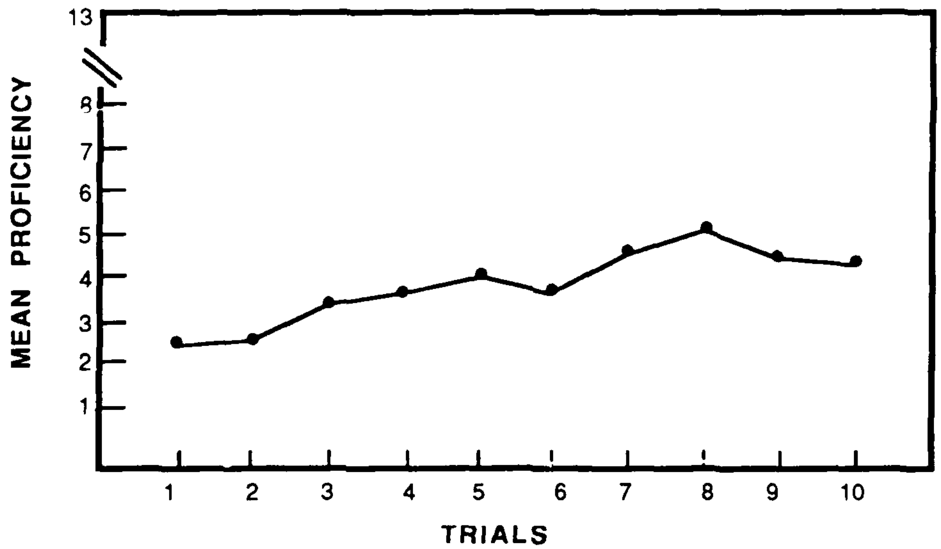
Hovering Tasks (copilot/gunner)



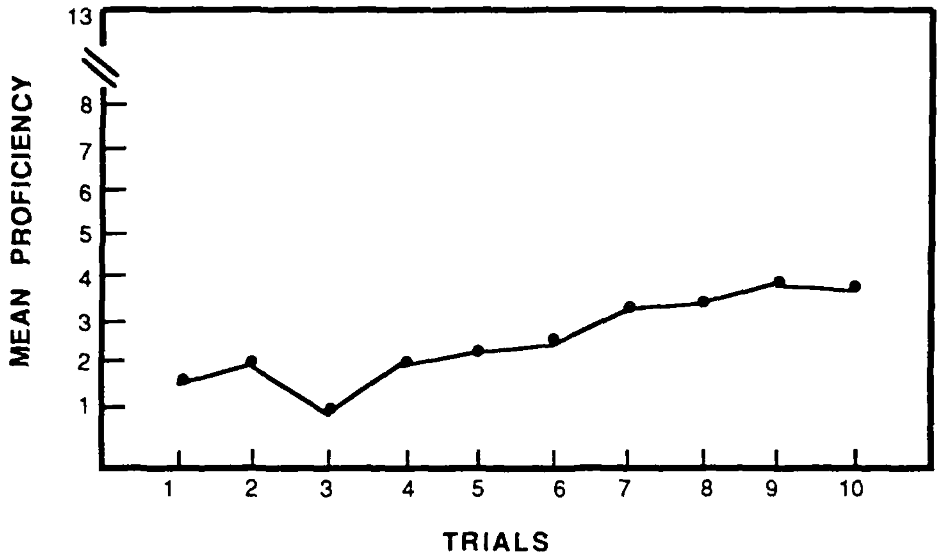
Low Level Autorotation (copilot/gunner)



Normal Approach (copilot/gunner)



Shallow Approach to a Running Landing
(copilot/gunner)



Standard Autorotation (copilot/gunner)